JOURNAL OF

METALS

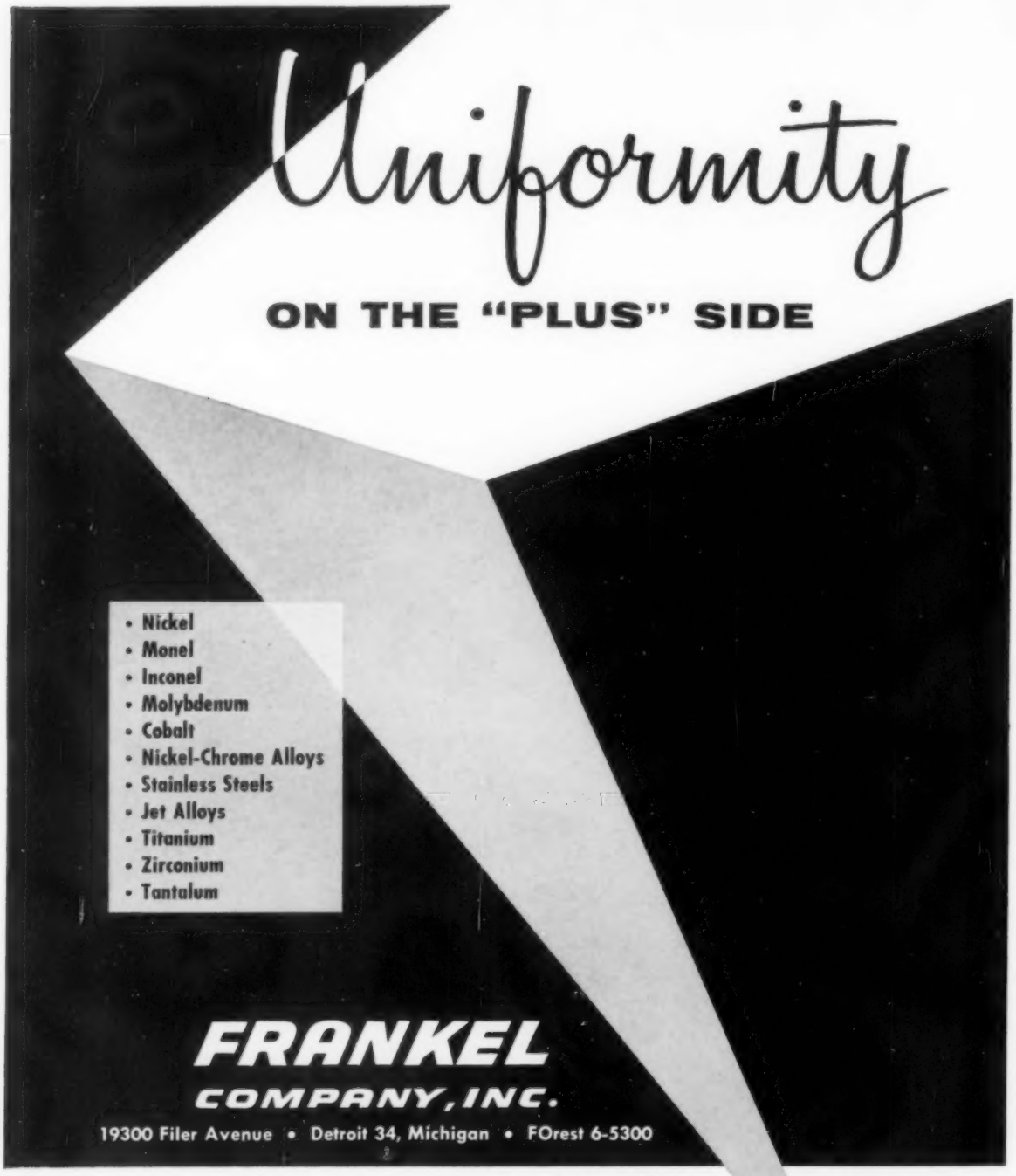
AUGUST 1958

IN THIS ISSUE

CUBE ORIENTED SHEET

PROCESSING HIGH TEMPERATURE METALS

IRON FROM COPPER CLIFF



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JOURNAL OF

METALS

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August, 1958

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EDITORIAL STAFF: Editorial Director, Rixford A. Beals; **Managing Editor,** F. Weston Starratt; **Associate Editor,** James J. Burke; **Production Editor,** Otto Johnson; **Editorial Assistant,** R. K. Larkin.
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PERSONNEL

THE following employment items are made available to AIME members on a nonprofit basis by the Engineering Societies Personnel Service, Inc. (Agency) operating in cooperation with the Four Founder Societies Local offices of the Personnel Service are at 8 W. 40th St., *New York 18;* 100 Farnsworth Ave., *Detroit;* 57 Post St., *San Francisco;* 84 E. Randolph St., *Chicago 1.* Applicants should address all mail to the proper key numbers in care of the New York office and include 8c in stamps (no stamped envelopes) for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

— MEN AVAILABLE —

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Chief Engineer, Development Engineer, or Sales Engineer, B.S. in Met. E., Registered, age 44. Excellent background, aircraft, light to heavy industry; design, development, product and processes, basic materials, fabrication, quality control, facilities and feasibility. Location immaterial but prefer Far West. M-193-Detroit.

Manufacturing Executive, B.S. M.I.T., age 39. Fifteen years intensive experience in production administration, labor relations, testing and quality control, design engineering, applied research and project development in nonferrous metals. Excellent coordinator. Prefer U. S. M-194-Detroit.

Metallurgist, B.S. Met. E. plus graduate work, age 26. One and one-half years experience chemical beneficiation research, one and one-half years experience research on corrosion of aluminum alloys. Available September. Location, immaterial. M-195.

— POSITIONS OPEN —

Patent Liaison Engineer, early 40s, with degree in chemistry, metallurgy, or physics, with some experience in invention reporting, disclosure preparation and general liaison work. Must be capable of operating without supervision and be able to deal tactfully all levels of scientific, engineering, and administrative personnel. Will be in charge of small patent liaison office. Salary approximately $10,000 a year. New York area. W6292.

Manager, Sales Engineering, 35-45, ceramic engineering graduate, with broad sales experience. Knowledge of porcelain enamel application to steel products highly desirable. Expected to develop new sales opportunities for porcelain enamel. Will report to top officer. Salary, $15,000–$20,000 a year. Location, East. W6255.

Metallurgists. a) Nonferrous Supervisor, M.S., prefer Ph.D., over 28. Two to ten years experience in research and development; knowledge nonferrous alloys including titanium, zirconium, vanadium, columbium, and tungsten. Will be technical and administrative director of a group involved in development of high temperature and special purpose alloys. Salary to $12,000. b) Sr. Physical Metallurgist, M.S., prefer Ph.D., 30 to 40. Must have two years experience in research and development and knowledge of physical metallurgy. Will be required to phase diagram and isothermal transformation studies in addition to the application of physical and metallurgical principle to casting of metals, alloy development, and fracture studies. Salary, $7200–$9000. c) Powder Metallurgist, B.S. to Ph.D., age 30. Must have one year in research and development and knowledge of basic sciences and metallurgy. Will perform research on dispersed phase activities, high temperature alloys, fiber metallurgy, cermets and nuclear fuel elements. Salary to $9000. d) Jr. Physical Metallurgist, B.S., age to 28. Must have one years experience research and development and knowledge physical metallurgy. Will phase diagram and isothermal transformation studies; investigate fatigue and fractures, and nucleation processes. Salary to $7200. e) Foundry Metallurgist, B.S., age to 40. Five years experience in research and development and knowledge of foundry operation and fundamentals of metal castings. Will conduct various research programs in the area of foundry methods as project leader. Salary $7200 to $9000. Employer will pay fee. Location, Chicago. C6861.

Metallurgical Engineer or Metallurgist, graduate, with production process experience in ferrous or nonfer-

rous fields covering alloy strip and wire. Salary, $6000–$8000 a year. Location, vicinity of Newark, N. J. W6041.

Engineers. a) Chemists, Ph.D. or equivalent, with experience in textiles, metallurgy, or detergency. Should have research background and interests. Salaries up to $12,000 a year plus bonus. b) Metallurgists, Ph.D. or equivalent, with research background and interests. Salaries up to $12,000 a year plus bonus. Location, Michigan. W5640.

Metallurgist, engineering degree, plus experience in practical metallurgy and fabrication of carbon and stainless steels. Knowledge of fuel element fabrication and/or other metallurgical fabrication applications peculiar to atomic power generation desirable. Salary, $6300–$8500 a year. Location, upstate, New York. W5534.

Physical Metallurgy Of Stress-Corrosion Fracture Conference

A Conference on the Physical Metallurgy of Stress-Corrosion Fracture will be held at the Mellon Institute, Pittsburgh, April 2-3, 1959. This conference will be sponsored by the Corrosion-Resistant Metals Committee of the Institute of Metals Division and the Pittsburgh Section of AIME. Cooperating with The Metallurgical Society of AIME in the technical program will be the Electrochemical Society, The National Association of Corrosion Engineers, and the American Society of Testing Materials.

An outine of the program follows:

Thursday, April 2

Session I—Introduction and Background
1. Significance of the Stress-Corrosion Problem
2. Characteristic of Stress-Corrosion Cracking

Session II—Theoretical Aspects of Stress, Corrosion and Fracture
1. Relationship of Microstress to Fracture (at or near solid-fluid interfaces)
2. Thermodynamic Relationship Between Stress and Chemical Potential
3. Relationship of Surface Topology and Structure to Environment

Session III—Experimental Aspects of Stress, Corrosion and Fracture
1. Role of the Corrosion Product
2. Stress and Microtopology
3. Stress and Electrode Potential

Friday, April 3

Session IV—Mechanisms of Stress-Corrosion Cracking
1. Environmental Aspects
2. Metallurgical Aspects
3. Behavior of Specific Materials

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An exceptional opportunity exists for a Powder Metallurgist and a Physical Metallurgist with proven ability to contribute to our many diversified research programs. We have over 20 years of experience in the research field and offer ideal working conditions and unusual opportunities for professional growth.

Our Powder Metallurgist opening requires a person with a minimum of a B.S. degree and several years of research experience who possesses a strong background in basic sciences and has previous training in dispersed phase activities, high-temperature alloys, fiber metallurgy, cermets, or nuclear fuel elements.

We desire a Physical Metallurgist with an advanced degree, preferably Ph.D., with an excellent understanding of physical metallurgical applications to work in areas of phase diagram and isothermal transformation studies, in addition to applying physical and metallurgical principles to the casting of metals, alloy development and fracture studies.

If you are an experienced research metallurgist and can qualify for the above positions, send a complete resume to:

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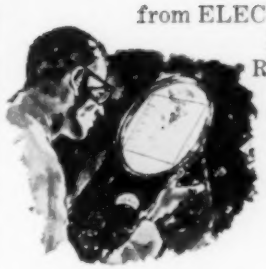

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Strength—On an island off the coast of Greenland, you can find the remnants of three large meteorites which the Eskimos have named "The Tent," "The Woman" and "The Dog." Only about one half of the meteorite mass remains, because native warriors and craftsmen worked for untold centuries to rip away pieces of the heaven-sent alloy for vital weapons and tools. So it is today, that man first turns to steel when he needs a versatile metal of great strength.

If strength were the only consideration of the designer, his job would be simple: pick the strongest steel he can afford for the job. But invariably, he is enmeshed in a spider's web of other problems. He needs varying amounts of corrosion resistance, toughness, weldability, fatigue or wear resistance, formability. To cap it, he is asked to choose from a vast range of different steels, at different prices, with different combinations of properties. Then come the added complications of heat treating, and the fact that production techniques may have a profound effect on several important properties of the steel he has chosen.

But underlying all this, one fact remains: In theory, there is one best steel for any application. When you know the performance requirements and the cost problems, when you are intimately familiar with all the properties of all the available steels, you can usually settle on one that will result neither in overdesign nor underdesign. And you are almost certain to find that steel in the great family of USS Design Steels, a selection unmatched by any other producer in the world.

For careful design, when cost is a problem, the selection of the best steel should be made by a skilled metallurgist—either on your staff or ours. Write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

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STEELS FOR DESIGN

Lower Left—Problem: Several of the stop logs fabricated by Montreal Locomotive Works for the St. Lawrence Seaway's St. Lambert Lock had to be made extra-strong to withstand greater water pressure than typical of the other locks. But to insure ease of handling and interchangeability with the other logs, they couldn't be made larger. Solution: Logs were made of USS MAN-TEN Steel, one of several USS High Strength Steels. Benefit: MAN-TEN logs are much stronger, but have same weight and size as regular stop logs.

Lower Middle—Problem: On a lift truck, every pound of weight forward of the wheels reduces load capacity. Solution: Clark Equipment Co. designed lift truck carriage assembly from USS "T-1" Constructional Alloy Steel, reducing weight of assembly by 60%, compared to structural carbon steel. Benefit: Pay load was greatly increased, due to USS "T-1" Steel's 100,000 psi yield strength.

Lower Right—Problem: Heil Company wanted to design a very strong, corrosion-resistant tank trailer to haul corrosive solutions. Solution: Using Type 316 USS Stainless Steel, they developed the unusual ribbed design visible in the picture. Benefit: Stainless Steel's strength helped to give greater beam strength to the tanker. Its corrosion resistance allows the tank to be cleaned easily, so it can be used to haul different liquids on different trips.

USS, Man-Ten and "T-1" are registered trademarks

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Indian Institute has U. S. chapter

The Indian Institute of Metals recently chartered its first chapter outside of India, at the Carnegie Institute of Technology, Pittsburgh, on May 14, 1958. The new Pittsburgh chapter began activities with some 40 members, many of them Indian students taking a year's study at the Carnegie Institute of Technology, under the INSTEP Program.

The Indian Institute of Metals, with 600 members serves the growing Indian steel industry in much the same way that the AIME serves steelmakers in the United States.

U. S. Department of Commerce Publications

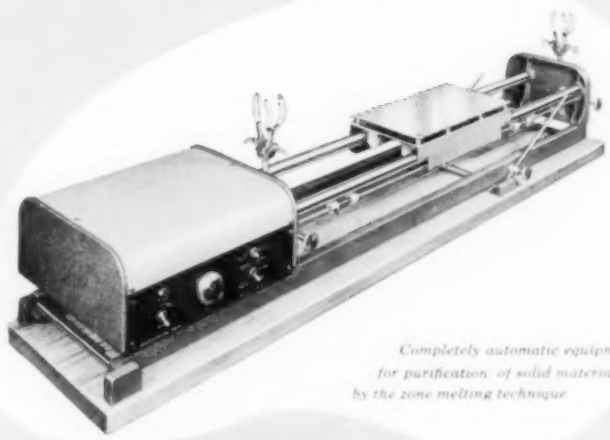
Request publications from:
Office of Technical Publications
U. S. Dept. of Commerce
Washington 25, D. C.

PB 131139 *The Engineering Application of the Absolute Rate Theory to the Creep of Some Aluminum Alloys*, by M. B. Hogan, University of Utah for Office of Naval Research, $1.75, 61 pp., 1956.

PB121127 *The Engineering Application of the Absolute Rate Theory to the Creep of Lead*, by M. B. Hogan, University of Utah for Office of Naval Research, $2.25, 83 pp., 1955.

The new **RSCo** MODEL 2470

ZONE MELTING APPARATUS



Completely automatic equipment for purification of solid materials by the zone melting technique

The **Model 2470** apparatus holds a glass or quartz tube inside of which is placed the charge of material to be purified. A moving table holds either induction heating coils or electric resistance heating rings which surround the tube. A synchronous motor and variable speed reducer drive the table at a constant rate variable from 0.36 to 9 inches per hour. Adjustable stops limit the table travel and actuate a rapid return mechanism. Multiple-pass zone melting is thus completely automatic.

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ORNL-2366 *Progress Report on Raw Materials for May 1957*, Chemical Technology Div., Oak Ridge National Laboratory, $1.00, 30 pp.

ORNL-2380 *Progress Report on Raw Materials for June 1957*, Chemical Technology Div., Oak Ridge National Laboratory, $1.00, 36 pp.

NLCO-677 *Measurement of Real Density of Powdered Orange Oxide (UO_3)*, 75¢, 16 pp., 1957.

PB 131090 *Practical Vacuum Treating of Non-Ferrous Melts at the U. S. Naval Gun Factory, Washington, D. C.*, by V. DePierre, U. S. Naval Gun Factory, 75¢, 26 pp., 1956.

San Francisco Section Sponsors Paper Contest

The AIME San Francisco Section is conducting a student prize paper contest this year in addition to the AIME annual national contest. The executive committee of the Section has also decided to raise the awards for the students at the University of California from $50 to $100.

The best graduate and undergraduate papers will each be awarded $100. The winning local papers then will be entered by the Section secretary in the national award contest. The papers are to cover a topic relating to some phase of mining, metallurgical, or petroleum engineering.

PB 131108 *A Procedure For the Elastic Stress Analysis of Threaded Connections Including the Uses of an Electrical Analogue*, by J. H. Flanagan and J. I. Bluhm, Watertown Arsenal Laboratory, U. S. Army, $1.25, 42 pp., 1955.

PB 121877 *Evaluation of Welded Joints Between AISI 347 Stainless Steel and 70-30 Copper-Nickel Alloy Tubes Under Thermal Shock Specimen No. 3*, by W. E. Clautice and R. W. Stevens, U. S. Naval Engineering Experiment Station, $1.25, 49 pp., 1955.

PB 121834 *An Investigation of the Fatigue Characteristics of Leaded Alloy Steels*, by G. W. Brock and G. M. Sinclair, University of Illinois for Bureau of Ordnance, U. S. Navy, $1.50, 57 pp., 1957.

PB 121456 *Effects of Physical Variables on Delayed Failure in Steel*, by R. D. Johnson, H. H. Johnson, J. G. Morlet, and A. I. Troiano, Case Institute of Technology for Wright Air Development Center, U. S. Air Force, $1.25, 44 pp.

PB 121484 *A Quantitative Theory of Grain Boundary Movement and Recrystallization in Metals in the Presence of Impurities*, by K. Lucke and K. Detert, Brown University for the Air Force Office of Scientific Research, $1.00, 32 pp., 1956.

AERONUTRONIC SYSTEMS, INC. A subsidiary of Ford Motor Company, is undertaking expanded military and commercial programs involving the most advanced research, development, experimentation and prototype production at modern, new facilities overlooking the Pacific Ocean at Newport Beach, California. The following positions are open:

PHYSICAL METALLURGISTS, for research and development in high-temperature materials. Advanced degree and minimum of 3 years experience, including X-ray diffraction, metallographic inspection and experimentation with ultra-high temperature physical properties. Familiarity with powder metallurgical techniques preferred.

PHYSICAL CHEMISTS and PHYSICISTS, for the determination of high-temperature thermodynamic properties of solids and gases. Advanced degree and minimum of 3 years related experience required. Familiarity with experimental procedures necessary.

Qualified scientists and engineers are invited to contact Mr. L. T. Williams, Aeronutronic Systems, Inc., Building 18, 1234 Air Way, Glendale, California.

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FOR MATERIALS RESEARCH and DEVELOPMENT

These four important supervisory positions will interest men of proven ability in materials research and development. Each offers the mental stimulation of working beyond the boundaries of current technical knowledge.
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General Supervisor—Metallurgical Engineering

To supervise metallurgical liaison with design, manufacture and test of research and development equipment. This position includes supervision of mechanical metallurgy, joining development and physical properties testing. The candidate must possess at least ten years' applicable experience with a B.S. degree. Less experience will be required for candidates with advanced degrees. Previous experience must demonstrate clearly that the candidate is qualified to initiate and direct research and development programs in appropriate fields and to translate readily from laboratory tests to the solution of design, manufacturing and operational problems.

Supervisor—Analytical Chemistry

To direct analytical research and development and to supervise routine analytical work. Problems include analysis of trace elements in metals and gases, liquid metal analysis, and the development of new chemical methods to meet project needs. Ph. D. with three years' experience or M. S. with at least six years of relevant experience. Candidates must demonstrate ability to recognize problems and show initiative in conduct of projects.

Supervisor—Joining Development

To supervise research and development of welding, brazing, cladding and diffusion bonding techniques. Candidate must have a B.S. degree with at least six years of proven accomplishment in relevant fields. Ability to initiate and carry out development programs based upon practical and theoretical considerations will be required. Men with Ph. D. degree and two years' minimum experience in applicable work will be considered.

Supervisor—Alloy Development

To supervise alloy development including melting, fabrication and test evaluation. Candidate should have a good theoretical background with practical experience in applicable work. Ph.D. degree desirable with two years' minimum experience. Candidate with B.S. degree must have at least six years' strong experience.

Please send complete resume to Mr. L. T. Shiembob, Office 9

Employment Department

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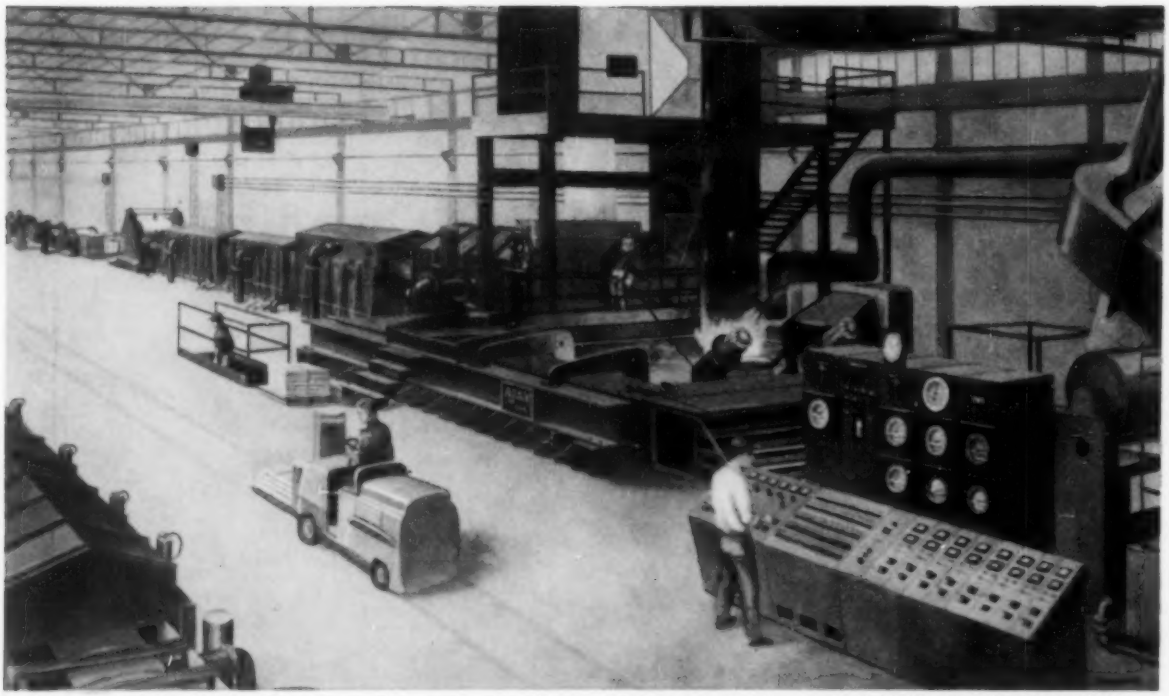

The above is a partial view of the two continuous galvanizing lines at the Martins Ferry, Ohio, plant of WHEELING STEEL CORPORATION. Both lines use AJAX 60 cycle induction galvanizing furnaces and zinc premelt furnaces. The main galvanizing furnace shown holds 175 tons of zinc, is rated 2000 kw, and produces over 40 tons per hour at speeds in excess of 300 feet per minute. These continuous galvanizing lines produce WHEELING's patented SOFTITE sheet.

60 Cycle induction galvanizing

has progressed from small beginnings a few years ago to a

present capacity of well over **one million tons per year.**

Here is an entirely new approach to an old art:

1. A refractory lined hearth in place of the iron kettle eliminates kettle replacement and iron pickup, drastically reduces dross formation.
2. Temperature control is precise, lag free, holds the melt at ideal galvanizing temperature at all times.
3. Gentle electromagnetic circulation facilitates alloy additions, keeps alloy uniform throughout the melt.
4. Clean and cool working conditions for hand dipping or continuous operations.

All these factors help to produce a galvanized coating of consistent superior quality and to attain high production at lowest unit costs.

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AJAX USA

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TRENTON 7, NEW JERSEY

60 CYCLE INDUCTION MELTING

Associated Companies: Ajax Electrothermic Corporation Ajax Electric Company

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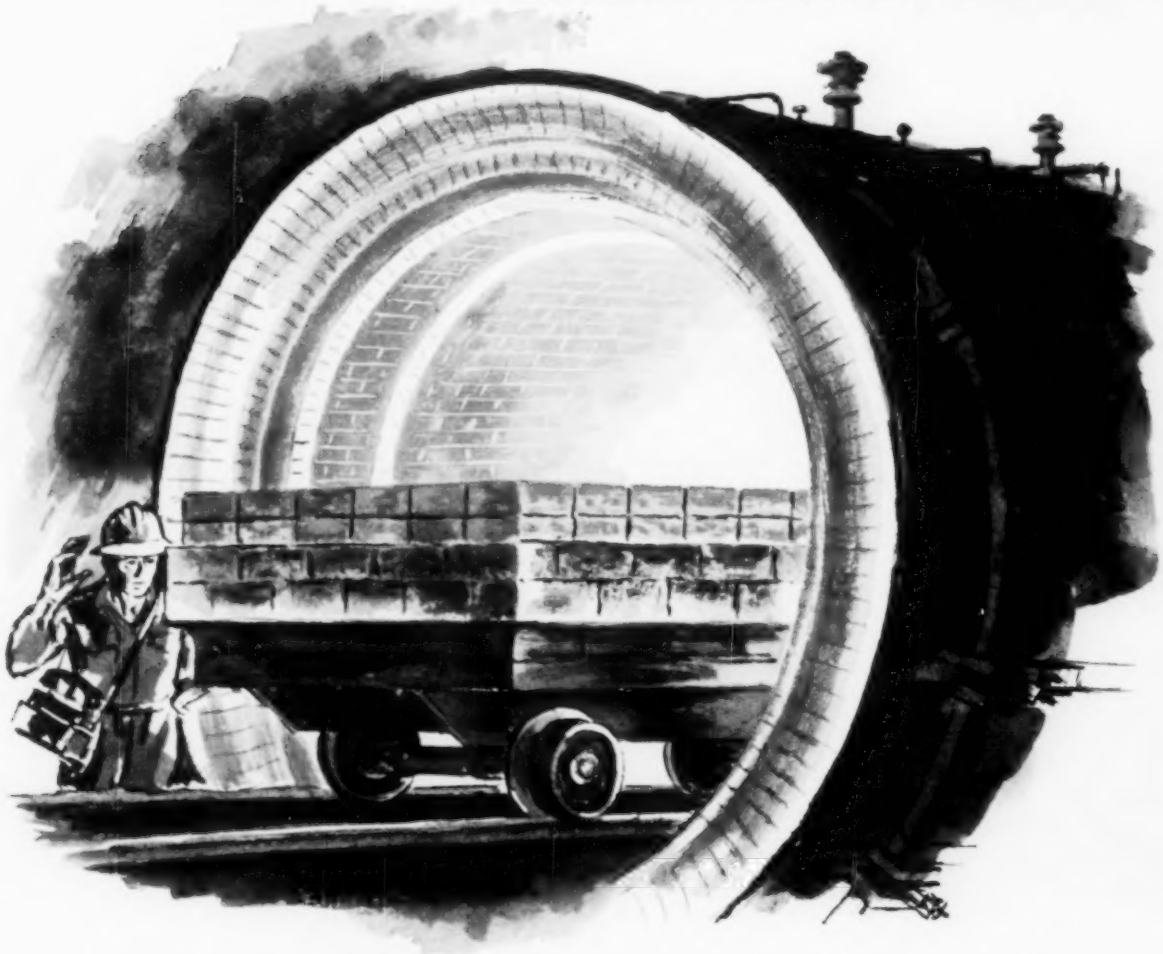

Metals find a new future in a vacuum!

Only a vacuum inside this giant furnace permits the high purification that makes possible many amazing new metals and alloys. This furnace at ELECTROMET's Marietta, Ohio, plant is over 100 feet long—largest of its kind ever built. It produces new high-purity chromium and manganese metals and very low-carbon ferrochromes which are major factors in the lower costs and improved properties of stainless steels and high-temperature alloys.

Vacuum processes also make possible the production and fabrication of capacitor-grade tantalum, reactor-grade columbium, and vanadium metal. These metals now make significant contributions to the aircraft, electronic, missile, and nuclear industries.

ELECTROMET scientists and engineers continually work toward further advancement in vacuum technology. At the same time, they develop new and useful alloys and metals . . . find practical solutions to customers' problems in using ferro-alloys.

Want to know more about recent developments in the field of vacuum-quality alloys and metals? ELECTROMET can help.

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PERSONALS

Hugh S. Ferguson, a consultant and director of W. R. Grace and Co., has been elected to the board of directors of National Research Corp., Cambridge, Mass.

Edward H. Fisher was recently elected as president of Tube Reducing Corp., Wallington, N. J. He recently joined Tube Reducing, having been associated previously with Oliver Corp., Chicago, as vice president and manager of its Special Products Division.

Walter W. Goehring, formerly manager of manufacturing for the Can Division of Crown Cork & Seal Co. Inc., has been appointed manager of the manufacturing department of F. J. Stokes Corp., Philadelphia.

C. W. Diven, Jr. has been elected president of the Steel Club of Philadelphia, an organization made up of steel sales representatives working in the greater Philadelphia area. He is district sales manager for Sharon Steel Corp. Elected to serve with Diven are: **A. W. Taylor,** Carpenter Steel, vice president; **C. W. Test,** Youngstown Sheet and Tube, secretary-treasurer; and two directors, **G. S. Berry** of Pittsburgh Steel and **Eric C. Anderson** of Republic Steel Corp.

Frederick W. Burgie, previously assistant sales manager of the Doehler-Jarvis Division of National Lead Co., Toledo, Ohio, was recently appointed general sales manager of the division.

Carter Kissell was elected president of the National Malleable & Steel Castings Co., Cleveland, and **Cleve H. Pomeroy** was named chairman of the Board of Directors.

John W. Easton was recently appointed manager, aluminum sales for Revere Copper and Brass Inc., New York City. He previously was manager of aluminum sales for Revere's Baltimore Division.

Frank W. Donavan has been appointed to the board of directors of Hanson-Van Winkle-Mining Co., Matawan, N. J. Donavan is a partner of the law firm McClintock, Fulton, Donavan & Waterman in Detroit.

Joseph V. Petrocelli has been appointed head of Electro-chemical Section of the International Nickel Co.'s Research Laboratory at Bayonne, N. J. He was formerly director of research and development for the Patent Button Co., Waterbury, Conn.

Frank A. Guba recently retired as manager, market research & development for the Alloy Tube Division of the Carpenter Steel Co., Union, N. J., after completing 17½ years of service. In retirement, Guba plans to continue in the field of stainless steel as a consultant and a manufacturers representative.

John H. Corson, previously manager of the Carpenter Steel Co.'s Research Laboratory, has been appointed manager of the company's Webb Wire Division, New Brunswick, N. J.

Carl F. Leitten was recently elected as president and chief executive officer of the Electro Refractories and Abrasives Corp. of Buffalo. He succeeds **Grant S. Diamond** who has held the office for 14 years and has now become chairman. Leitten has also been elected president of the Electro Refractories and Abrasives Corp. Ltd., of Cap de La Madeleine, Que., a wholly owned subsidiary that produces silicon carbide.

Burton S. Payne, Jr., was recently appointed to head the metallurgical research and development group in the Research Division of the Pfaudler Co., Rochester, N. Y. Payne joined Pfaudler in 1956 as a metallurgist.

Thomas E. Moffitt was recently elected president of the Hooker Electrochemical Co., Niagara Falls, N. Y. He succeeds **Bjarne Klaussen,** who is retiring but will remain on the board.

Five personnel changes were recently announced in the Warehouse Division of the Jones & Laughlin Steel Corp., Indianapolis, Ind. **Charles A. Burke** has been appointed to the newly-created position of division manager of sales, flat rolled products. He was formerly manager of sheet and strip products for the division. **Edwin S. Lewis** has been named to the new position of special sales representative, national accounts for the warehouse division. Lewis was previously a sales trainee in the division. **S. H. Coddington** has been appointed to the newly-created position of division manager of operations, flat rolled products. He formerly served in various sales capacities with the Solar Steel Corp. **William N. Vaughan** has been promoted to assistant office manager of the warehouse. He previously was assistant office manager for J&L's Chicago district warehouse. **Richard K. Dobbs** has been promoted to manager of sales, flat rolled products for the Indianapolis warehouse. Dobbs, who succeeds Burke, formerly was assistant manager of sales, sheet and strip products, at the warehouse division.

William Hegmann, Jr., of Ft. Smith, Ark., has resigned his position as sales engineer for Walsh Refractories Corp., and is now engaged in private consulting work in the metallurgical, mechanical and ceramic field.

E. G. West, technical director of the Aluminium Development Assn., England, is now making an extensive tour of Canada and the United States. He is visiting the principal aluminum producers and fabricators. West's itinerary includes Oakland, Louisville, Pittsburgh, Chicago, Richmond, Washington, and New York.

Harlan W. Diefendorf, has been promoted from assistant superintendent of melting, to superintendent, at Crucible Steel Co. of America's Sanderson—Halcomb works in Syracuse, N. Y.

Charles R. Gebel, sales representative in the Pittsburgh area for the Electrode Div., Great Lakes Carbon Corp., was recently appointed manager of the company's new branch office in Pittsburgh.

Edward Crowell Nelson recently joined the staff of the Tonawanda Laboratories of the Linde Co., a Division of Union Carbide Corp. He is presently working in the metallurgical section of the research laboratory.

Fred A. Kaufman, previously vice president, sales and manufacturing, of the McKay Co., Pittsburgh, has been elected a vice president of Universal-Cyclops Steel Corp., Bridgeville, Pa. and general manager of the new Refractomet Division at Bridgeville.

John J. Hannigan, was recently appointed superintendent, open hearth steel dept. of Alan Wood Steel Co., Conshohocken, Pa. He has been associated with the company since 1951, and was formerly assistant open hearth superintendent.

Leslie S. Wilcoxson, has been elected a member of the board of directors of Babcock—Wilcox & Goldie—McCulloch Ltd., Galt, Ont., Canada. Wilcoxson is vice president in charge of the boiler division and a director of the Babcock & Wilcox Co. of the United States.

Edwin J. Duncan, recently joined Latrobe Steel Co., Latrobe, Pa., as a metallurgical engineer.

United States Steel Corp., Pittsburgh, has appointed **J. D. Rollins** as vice president, facilities planning; and **E. L. Tindall** as vice president, design and construction.

Roger T. Miller, was recently promoted to manager, ferro-alloy market production, Electro Metallurgical Co., Division of Union Carbide Corp., New York, N. Y.

Two of the newly appointed administrative vice presidents recently appointed by United States Steel Corp., Pittsburgh are: **James C. Grey,** raw materials; and **R. M. Loyd,** international and raw materials—staff.

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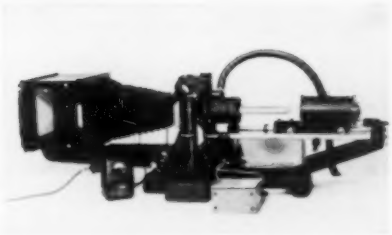

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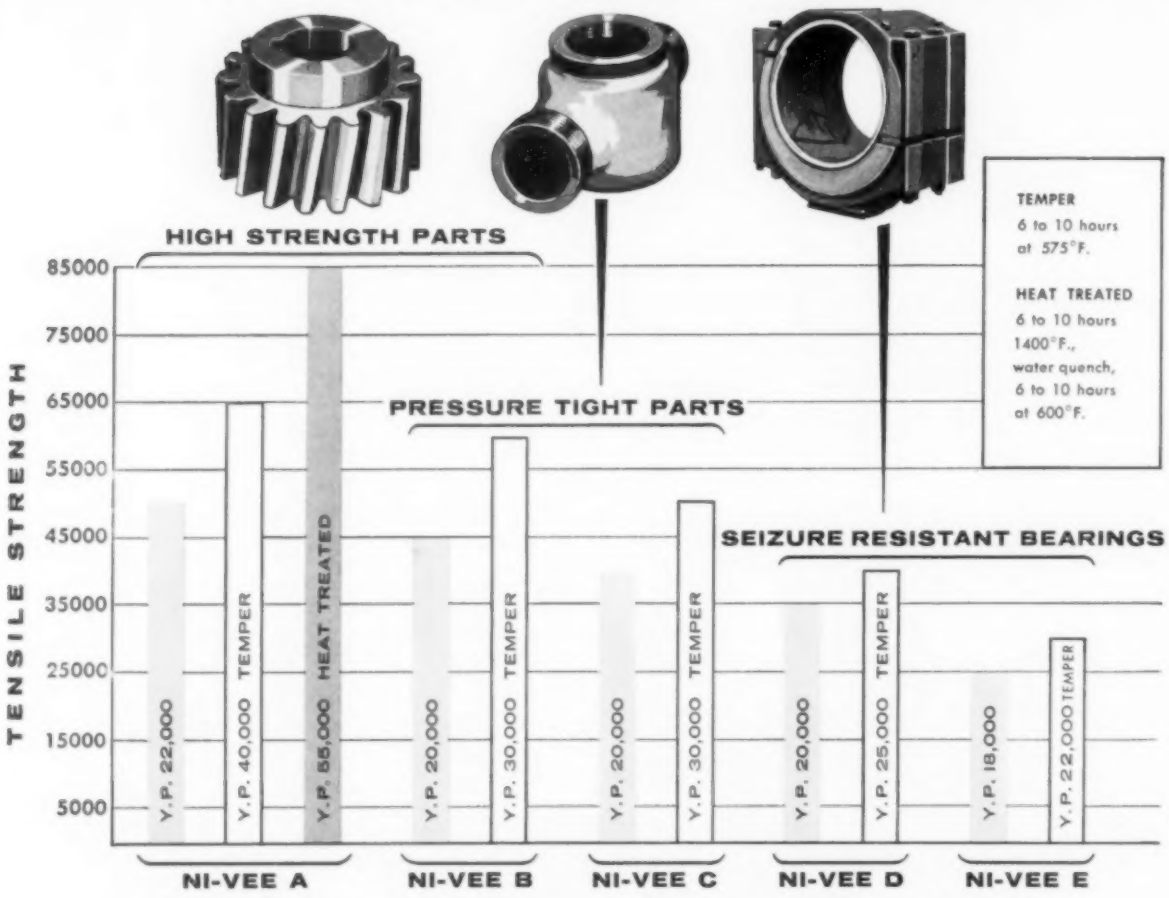
TYPICAL NI-VEE BRONZE PROPERTIES



5 high-performance bronzes

These versatile Ni-Vee alloys provide a range of properties that satisfies the requirements of most copper-base castings

The chart shows the range of tensile properties of the five Ni-Vee* bronzes and indicates the types of castings made with these alloys.

As you can see, you can satisfy the majority of your specifications for quality copper-base castings from among these five versatile Ni-Vee materials. Their "As Cast" mechanical properties – especially yield strength – surpass those of comparable G and leaded bronzes and red brasses.

The chart also shows what simple heat treatment does to step up their properties. Bear in mind that values taken from the chart are typical. In practice, higher values can be obtained.

Ni-Vee extras

You can expect superior performance from all five Ni-Vee bronzes. For example. Ni-Vee B, C, D, and E (the leaded group) can be used for castings of all three classifications shown. Ni-Vee A provides extreme strength. Ni-Vee E gives you extreme resistance against galling or seizure. The low zinc group (Ni-Vee A, B, D and E) show little tendency to dezincify, insure top-notch resistance to stress corrosion. All five, of course, have the excellent general corrosion resistance of copper reinforced by a 5% nickel 5% tin content.

Helpful booklet gives complete information on Ni-Vee bronzes

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Soviets push copper output

Soviet production of refined copper in the period 1946-1956 is estimated to have almost tripled and to have risen from 8.5 pct to 12 pct of world output. This is revealed in a report by the Business and Defense Services Administration of the US Department of Commerce. While much of the smelting capacity of the USSR is still located in the Urals, ore reserves are depleted, and more than half of the copper deposits are reportedly located in Kazakhstan. Heavy expenditures are being made to develop this region, which includes one of the largest copper smelters, the Balkhash combine. It uses porphyry ore from the adjacent Kounrad deposits. Other important copper producing regions are Uzbek and Armenia, but some copper is also produced in the Kola Peninsula and at Minusinsk in Siberia. Recent discoveries of ore have been reported on the edge of the Chuki Peninsula, near Alaska.

But Copper imports still required

The 1956 production of refined copper in the USSR is estimated at some 550,000 short tons with imports of about 20,000 tons. The Sixth Five-Year Plan (1955-1960) called for an increase of 60 pct in the production of refined copper, but the US Department of Commerce does not believe that this will be met. Furthermore, during the same period, the USSR expects to increase electric-power generating capacity from 192 to 320 billion kw-hr. Thus, it is believed that the USSR will continue to require imports of copper to meet mounting demands, particularly for increased electric power output.

Fastest growing aluminum industry . . . USSR

By 1957, the Soviet bloc aluminum industry attained a primary aluminum production estimated at 700,000 tons, or 22 pct of the world's total, reports the July-August issue of Reynolds Review. Informed observers predict that the Soviet bloc will have a capacity of 1,430,000 tons by 1961.

But Soviet aluminum demand declines

With the advent of the missile age, military requirements for aluminum dropped appreciably. In America, where over 90 pct of the aluminum production goes into civilian consumption, changed military requirements did not have the impact that they had in the USSR, where the apparent result was a surplus of aluminum. Nevertheless, it appears that the Soviets did not cut production—in 1955 they began exporting to the world market at cut-rate prices.

US aluminum producers worried

Rolled into sheet by European mills, a small quantity of Soviet aluminum did reach the US market and was sold under the price of domestic sheet. This has been the call for action! US aluminum producers were already concerned by some 600,000 tons of idle capacity, prospects of wage increases, and a cessation of Government stockpiling. Calls for Government action are now being heard in Washington, while for Canadian producers there was further alarm . . . possibility of increased US tariffs.

News of EDUCATION

INTER-UNIVERSITY CORPORATION

Twenty-six leading educational and research institutions have formed an inter-university corporation to be known as **Associated Midwest Universities (AMU)**. Dr. James H. Jensen, provost, Iowa State College, Ames, Iowa, is the initial president of the new organization.

It is planned to establish headquarters for AMU at the Argonne National Laboratory's main site near Lemont, Ill. The AMU has been incorporated as a non profit corporation under the laws of the State of Illinois.

The primary objective of Associated Midwest Universities is to see that the great AEC-sponsored laboratory and the educational and research talent of the participating institutions are utilized to the fullest possible extent. It is anticipated that AMU will be a successor to the organization formerly known as Participating Institutions of Argonne National Laboratory.

LEHIGH ALUMNI AWARDS

Two AIME members were numbered among the six recipients of the Lehigh University Alumni Association awards, presented at the annual Alumni Reunion banquet, held on May 30, 1958.

A. Dudley Bach, Jr., president of the New England Metallurgical Corp., Boston, Mass., and **Marcus W. Saxman**, president of the Latrobe Steel Co., Latrobe, Pa., received the awards which are presented to individuals "who through the years have distinguished themselves both by personal achievement and service as to bring lasting recognition to themselves and to Lehigh University."

TITANIUM TECHNICAL MEETING

This fall instead of holding a titanium metallurgy course, **New York University** will have a technical meeting on titanium scheduled for September 8 and 9th. The subject will be heat treatment and alloying of titanium.

On the evening of September 9th, a panel discussion on the *Present and Future of Titanium* will be held. If further information is desired, it may be obtained by writing *Harold Margolin, Associate Professor of Metallurgical Engineering, New York University, University Heights, New York 53, N. Y.*

BOOKS

Metal Cleaning Bibliographical Abstracts, 1957 Supplement, ASTM Special Technical Publication 90-D, American Soc. for Testing Materials, 1916 Race St., Philadelphia 3, Pa., 44 pp., $2.00.—This book supplements Metal Cleaning Bibliographical Abstracts, STP 90-B, which covers the years 1842 to 1951; and the 1954 supplement, STP 90-C, which covers the years 1952 through 1954. This 1957 supplement brings the references up to 1956. These abstracts are designed to make the published data on metal cleaning readily available to persons concerned with the production, finishing, and maintenance of metal products. References are arranged by year, then by author or by journal if author is anonymous. The references are numbered consecutively and in addition, are indexed by subject, author, specification, and patent. Over 225 new references are contained in the book, including coverage of cleaning by ultrasonic means; cleaning stainless steels, titanium; and semi-conductors such as germanium. •

The **Thirteenth Annual Meeting** proceedings of the Metal Powder Assoc., (Chicago, April 30-May 1, 1857) Vol. 1—General Session on Powder Metallurgy $4.00, and Vol 2—Ferrite and Electronic Core Session, $3.00, *Metal Powder Assoc.*, 130 W. 42 St., New York 36, N. Y.—Volume 1 includes papers on: activated sintering; production and characteristics of chemically precipitated copper powder; fiber metallurgy; new developments in metal powder filters and new developments in diamond products using metal powders. Among the papers covered in volume 2 are: how to take advantage of magnetic core materials; characteristics and applications of ceramic permanent magnets; characteristics and present requirements of ferrites; and latest developments in magnetic storage and switching applications. Remittance in advance is required on all overseas orders and should include $1.00 for postage. •

Bibliography on Adhesive Bonding of Metals, ESL Bibliography No. 12, Compiled by the *Engineering Societies Library*, 29 W. 39 St., New York 18, N. Y., 23 pp., $2.00.—This is a selected list of over 150 annotated references to books and magazine articles published from 1947 to 1957, covering all aspects of adhesive metal-to-metal bonding. Included are references to theory, technology, properties and methods of application. In addition to application in the aircraft industry, the references deal with many other products such as tools, machinery parts, electrical apparatus and wiring, pistons, metal window frames, furniture, bicycles, etc. •

Better Wage Incentives, by Phil Carrol, *McGraw-Hill Book Co. Inc.*, 222 pp., $4.75.—A practical guide telling how to set up and effectively maintain a good incentive program. It especially shows the various types of incentive grievances, how to plan and prevent them, and what to do about them if they do arise. The thorough treatment includes information on incentives for foremen, how to prepare for incentive arbitration if it becomes inevitable, and economics of incentives. Complete with line illustrations, graphs, and tables. •

Methods For Emission Spectrochemical Analysis, *American Soc. for Testing Materials*, 1916 Race St., Philadelphia 3, Pa., 504 pp., $7.00, 1957.—This second edition brings up to date the first extensive compilation of emission spectrochemical methods published by ASTM in 1953. Covered are the spectrochemical analysis of the most important ferrous and nonferrous metals and alloys, as well as several nonmetallic materials such as slags, ceramics, caustic liquor, petroleum products, etc. Suggested practices are included on the installation and safe operation of a laboratory specifying excitation sources, designating shapes and sizes of electrodes, sampling, and computations. More than 800 spectral line pairs, tested in continuous laboratory applications, are provided. In addition to the 65 suggested practices and methods, there are 16 recommended practices and tentative methods. •

Inorganic Syntheses, Vol. V, by Therald Moeller, *McGraw-Hill Book Co. Inc.*, 265 pp., $6.00.—This fifth volume of the series, retains the policy of having each synthesis carefully checked in at least one independent laboratory. This has provided a means of determining the exactness and correctness of each procedure and often a means of increasing the usefulness of the procedure through incorporation of the findings of the checker. Each synthesis has been edited after checking and approved in the final form by both submitter and checker before publication. That many of the procedures either originated or were checked in industrial laboratories may be taken as indicative that the material in the book is of both technical and fundamental interest. •

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EDITORIAL

Transactions to Adopt New Printing Process

by A. W. Thornton, Chairman

Publications Committee

CARRYING out one more feature of the 1957 Publications Committee Report, the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME will be printed by the photo-offset method, starting with the August issue.

This will mean many things to the members of The Metallurgical Society:

- Faster publication of accepted papers in the TRANSACTIONS.
- More accurate reproduction of micrographs.
- Potential for expanding the volume of material published without increasing the price.

The TRANSACTIONS is ideally suited for the photo-offset process, as it carries advertising only on its covers. Extra expense for reproduction of advertising copy makes the process less desirable for a magazine, such as JOURNAL OF METALS. All of these details and many more were carefully evaluated by the Publications Committee before the decision was made to change over to photo offset. Bids from leading printers both in this country and abroad were considered, and these included bids for letterpress (the present process) as well as photo offset. The contract was awarded to Edwards Brothers Inc., of Ann Arbor, Michigan, which has a long-standing reputation in the field.

Revue of policy changes

It might be wise, at this point, to review the sweeping changes that have taken place in the publications policy of The Metallurgical Society since the first of this year, as a result of the 1957 Publications Committee Report. In January, all Transactions papers were removed from the JOURNAL OF METALS, and the Feature Section of this magazine was given a long-needed expansion. All Transactions papers, including those that formerly appeared in the quarterly JOURNAL OF METALS Supplement, were published exclusively for the first time in TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME. The first issue appeared in February, and it is published on a bi-monthly basis.

In early May, Dr. Gerhard Derge, Jones and Laughlin Professor of Metallurgy at the Carnegie Institute of Technology, was appointed Editor of the TRANSACTIONS, and in this position he coordinates the work of the three divisions in reviewing and selecting manuscripts for publication. He is, thus, charged with upholding the high standards of quality and scientific merit which have marked the AIME Transactions for over a half-century. We are sure that under Dr. Derge's guidance this task will be most ably carried out.

The change to photo offset printing is but another step by The Metallurgical Society in continuing and expanding its services to members so that they may keep themselves well informed—professionally informed—of activity in the field.

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CUBE ORIENTED MAGNETIC SHEET

A Major Advance in Magnetic Materials

by G. W. Wiener and Klaus Detert

Within the space of one week last year, the two leading producers of electrical equipment, General Electric Co. and Westinghouse Electric Corp., both announced the development of a cube-oriented silicon-iron transformer sheet.

Below, JOURNAL OF METALS *presents two papers, one from Westinghouse, on the nature and uses of the new material, and one from General Electric, describing its magnetic properties.*

Although not mentioned in the papers, the General Electric product is called "Four-Square," while Westinghouse has chosen "Cubex" as the trade name for its cube-oriented sheet.

CONSUMPTION of electrical power in this country is now doubling once every nine or ten years. To meet this demand, the trend in the field of power generation and distribution has been to increase the size of single units to 400,000 kva. For motors and control devices, high efficiency, compactness, and reliability are the goals. If this growth trend is to continue, improved and new materials, together with advances in design, are vitally necessary. These requirements can be met only with alloys that will operate at higher flux densities and at the same time, have decreased energy losses. The newest alloy to meet these requirements is cube-oriented silicon-iron.

To obtain maximum quality of any soft magnetic alloy, four factors must be considered: control of impurities, reduction of internal stresses, control of crystal size, and control of crystal orientation. Of these four, crystal orientation has been the most difficult to accomplish, and a major research effort has been concentrated in this field.

At the start of this investigation, it was decided that an alloy of 3 pct silicon-iron would be the basic composition to be studied. This alloy has a saturation magnetization close to that of pure iron; a high resistivity; one crystal structure up to the melting point; and is a basically cheap raw material. Three percent silicon-iron has a cubic crystal structure. This cube has three mutually perpendicular directions of magnetization. If a magnetic field is applied parallel to any of these directions, minimum energy is required to magnetize the sample.

Three magnetic materials compared

Consider for a moment, three types of magnetic materials, random, singly-oriented, and cube-oriented. The random type may be likened to a bag of blocks that has been thoroughly shaken. This is the type of structure associated with hot-rolled silicon steel sheets. With this random array of cubes, it is obvious that the applied magnetic field cannot be oriented in such a way that it is always parallel to a cube face.

G. W. WIENER and KLAUS DETERT are with Westinghouse Electric Corp. Research Laboratories, Pittsburgh, Pa., and Vacuumschmelze A.G., Siemens-Halske, Hanau, Germany, respectively.

Singly-oriented steel consists of cubes standing on edge, hence it is often called *cube on edge orientation*, Fig. 1a. The arrow shows that the easy direction of magnetization lies only along one direction of the sheet. In fact, lines representing the other cube axis would extend out the top and bottom of the sheet at 45° angles.

The double, or cube type of orientation may be thought of as a tray of ice cubes. Then, the easy directions of magnetization are parallel to the length, width and height of the strip, Fig. 1b. This cube orientation is not the usual configuration found in iron and, therefore, special metallurgical processes had to be found in order to accomplish the desired result.

The obvious advantage of the new cube-oriented alloy is that the magnetic flux can now turn corners easily. This is shown by comparing some magnetic properties of cube-oriented material with singly-oriented material in rectangular punchings. Loss curves show that the new material is considerably better than the corresponding singly-oriented strip.

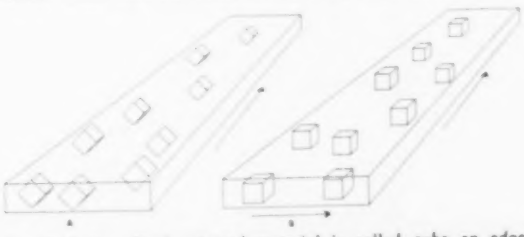


Fig. 1—Left— Singly-oriented material is called *cube on edge orientation* and has only one easy direction of magnetization. Right—All cubes lie on their faces in doubly-oriented silicon steel and are within 20° of the rolling direction or 90° to it.

Will enhance transformer performance

The value of crystal orientation has long been recognized in the design of transformers. But each design is based on singly-oriented material, and fabrication techniques take every possible advantage of the one easy direction of magnetization. The spiral *C* core design winds the singly-oriented material in a coil, while the shell form construction takes punchings from the material and arranges the strips at right angles to each other, Fig. 2. In gen-

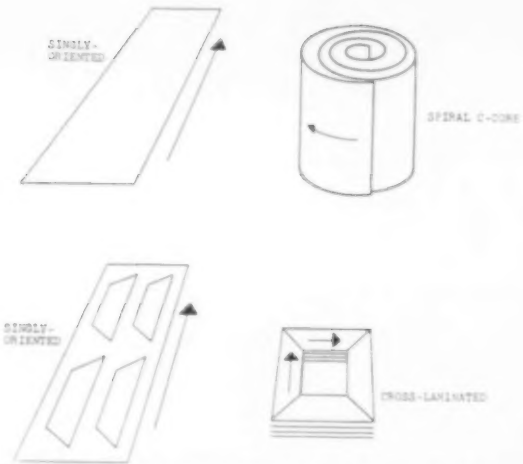


Fig. 2—Singly-oriented material is used to maximum advantage by coiling strip into a coil for C-core transformers. For shell form construction, mitered punchings from singly-oriented material are arranged at right angles to each other.

...rator stator core assemblies, if maximum use is to be made of singly-oriented material, then it would be necessary to punch the teeth in one direction, the wide curved section in another direction, and weld the two together; A single punching from the new cube-oriented material could satisfy this two-direction orientation requirement.

The formation of this cube orientation depends on what is believed to be a new mechanism of crystal growth and on carefully controlled structure during the metallurgical processing. For this reason, a considerable amount of research and development is still required before this new material will be commercially available in all useful sizes. Experiments in the laboratory have already shown that the alloy can be made in thicknesses currently being used in 60-cycle electrical apparatus, and small amounts have been produced in thicknesses useful for high-frequency applications. Laboratory quantities of the material have also been made from conventionally melted ingots produced at a steel mill. Under the best conditions, test strips have been made that approach 100 pct orientation with regard to the cube plane and the easy magnetization directions of the cube are all within 20° of the rolling direction or 90° to it.

The experimental work done thus far has shown that cube-oriented iron alloys of the kind described can be made. The work required now will be to obtain a deeper understanding of the factors involved in the preparation of the material so that its widespread commercial use will be practiced in the future.

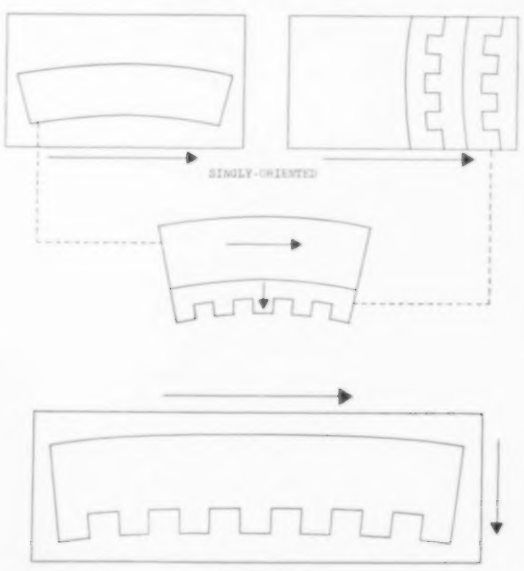


Fig. 3—Advantage of cube oriented sheet for construction of generator stator core assemblies can be readily seen; a single punching of singly oriented material replaces two punchings which were subsequently welded.

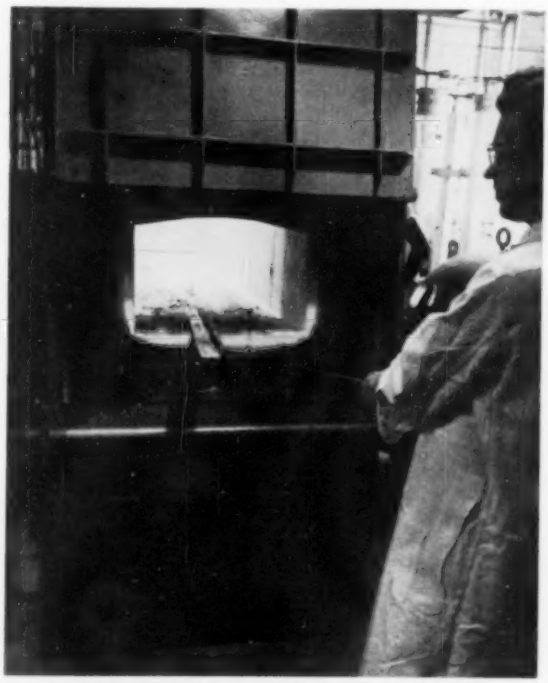


Fig. 4—A metallurgist pulls a sample of cube oriented sheet out of a furnace at the Westinghouse Research Laboratories.

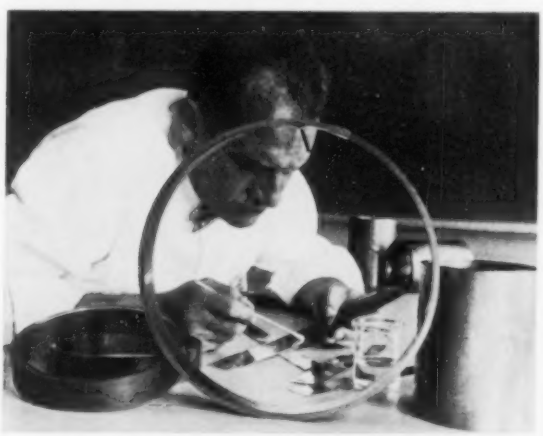


Fig. 5—R. B. Aspden, one of the metallurgists who worked on the project at Westinghouse, applies an etch to a strip of cube oriented sheet.

Magnetic Properties of Cube Textured Transformer Sheet

by J. L. Walter, W. R. Hibbard, Jr., H. C. Fiedler, H. E. Grenoble, R. H. Pry, and P. G. Frischmann

IRON and alloys of iron are magnetically anisotropic, that is, the magnetic properties are different along different crystallographic directions of the crystal lattice. The [001] directions, the edges of the cubic lattice, are the directions of highest permeability and lowest losses, the easiest directions to magnetize. *Grain oriented* silicon-iron magnetic sheet was developed to take advantage of this anisotropy.

The crystals of the sheet are oriented such that the majority of the crystals have a cube-direction parallel to the rolling direction of the sheet and a (110) plane parallel to the plane of the sheet. Thus, one easy direction of magnetization is parallel to the rolling direction. Electrical equipment, such as transformers, motors, and generators, are designed to take advantage of the easy direction of magnetization produced in the sheet. There are some limitations inherent in this material, however. The (110) planes of the crystal lattice are parallel to the plane of the sheet which places a [111] direction at 55° to the rolling direction and a [011] direction at 90° to the rolling direction in the plane of the sheet. Since the [111] and [011] directions are harder directions of magnetization than the [001] directions, higher losses and lower permeability result when the flux must travel at an angle to the rolling direction. This occurs, for instance, at the corners of a lapped-joint transformer core or when the flux must travel in a radial direction in the rotor or stator of a motor or generator. The increased losses lower the electrical efficiency and increase the amount of heat which must be removed from the machine. The most practical way to eliminate the high losses in the cross direction would be to arrange the crystal orientation of the material so that two [001] directions lie in the plane of the sheet. Thus the material would have one [001] direction parallel to the rolling direction and another [001] direction at 90° to the rolling direction. This is the well known cube texture commonly found in FCC alloys. Cube texture components in body centered cubic alloys of iron have been described by Sixtus.[1] Bozorth and Williams[2] and Dunn[3] prior to this work, and more recently by Ackerman et al,[4] and Möbius,[5] and Assmus et al.[6]

Cube textured magnetic sheet of 3 pct Si in iron has been developed and is now being produced in sufficient quantity to test in transformers, motors, and generators. This texture has also been produced in aluminum-iron or molybdenum-iron alloys and in any thickness of sheet or strip up to 0.100 in.

J. L. WALTER, W. R. HIBBARD, JR., H. C. FIEDLER, H. E. GRENOBLE, R. H. PRY, and P. G. FRISCHMANN are with the Research Laboratory of the General Electric Co., Schenectady, New York.

Magnitude of the texture

The magnitude of the cube texture of the polycrystalline material was determined by measuring the torque required to rotate a 1 in. diam disc about an axis normal to the plane of the disk in the presence of a uniform magnetic field of 1000 oersteds. This torque value was compared to the torque values obtained from a single crystal disc of the same thickness and composition tested in the same field. The single crystal disc, which also had a 1 in. diam, had a (100) plane within 1° of the plane of the disc. Since there are two [001] directions in the plane of the disc, the torque curve exhibits a four-fold symmetry. The curve of torque versus angle (from the rolling direction) for a typical polycrystalline disc is also of four-fold symmetry with easy directions of magnetization at 0, 90, 180, and 270° from the rolling direction. The ratio of the torque at 22.5° to the torque at 112.5° from the rolling direction is typically 0.95, which indicates that the texture is not

perfectly cubic. The ratio of these same two torques for the single crystal is 1.0.

To determine the magnitude of the texture of the polycrystalline disc one takes the ratio of the 22.5° torque of the polycrystalline sample to the 22.5° torque of the single crystal. A typical value for this ratio is 0.90, or 90 pct of the torque exhibited by the single crystal. Thus, the magnitude of the polycrystalline texture is known relative to a single crystal of the same orientation.

From this data and verifications by X-ray diffraction pole figures, it is evident that a high degree of cube texture can be obtained in silicon-iron.

DC magnetic properties

The dc magnetic test was used primarily as a means of confirming the type and magnitude of the texture obtained in the material. The test pieces were ½ x 3 in., small enough that properties could be obtained in both directions in the plane of the sheet. The samples were taken parallel to the rolling direction and at right angles to the rolling direction of the sheet. The properties of the material measured parallel to the rolling direction are given in Table I for both the cube textured silicon-iron and the *grain oriented* alloy.

The maximum permeability was obtained by measuring the slope of the line from H = 0 and B = 0 to the knee of the B-H loop. When similar samples of the two materials are measured at right angles to the rolling direction, the merit of the cube textured material becomes even more apparent. The properties of both materials measured at right angles to the rolling direction are given in Table II.

AC watt losses

Watt losses of single strips measured at inductions of 15,000 gauss and 60 cycles are given in Table III. The test samples were 12.7 cm long by 3 cm wide and were taken both parallel to and at right angles to the rolling direction. The losses are reported as total losses in watts per pound. Each value is the average of several tests.

Table I. DC Magnetic Tests Parallel to Rolling Direction

	Cube Textured	Grain Oriented
Maximum Permeability	116,000	55,000
Coercive Force, oersteds	0.07	0.08
Residual Induction, gauss, H = 0 oersteds	12,200	9,500
Induction at H = 2 oersteds	16,600	16,300

Table II. DC Magnetic Tests at Right Angles to Rolling Direction

	Cube Textured	Grain Oriented
Maximum Permeability	65,000	8,000
Coercive Force, oersteds	0.08	0.27
Residual Induction, gauss, H = 0 oersteds	11,500	1,750
Induction at H = 2 oersteds	16,000	11,000

Table III. AC Watt Losses, Watts per Lb

	Cube Textured	Grain Oriented
Parallel to Rolling Direction	0.56	0.60
Transverse to Rolling Direction	0.65	1.60

Transformer tests

Test transformers were made of both the cube textured material and the grain oriented material to determine ac watt losses and excitation currents. The transformers were of the *U-I* type with laminations 0.012 in. thick. The *U* punchings were taken with the sides parallel to the rolling direction of the strip. The *I* punchings were also cut parallel to the rolling direction and alternately butted against the open end of the *U* punching and stacked on the closed end of the *U* for the next layer. By use of laminations of this type it was possible to reduce the transverse flux path to one tenth of the total flux path. The energy loss in watts per pound versus induction, measured for both transformers, are plotted in Fig. 1. It can be seen from the figure that the losses of the cube textured material are approximately 60 pct of the losses produced by the grain oriented material when both are tested at induction of 17,000 gauss.

The excitation current for both transformers was determined for inductions from 10,000 to 18,000 gauss. It was found that the excitation current for the cube textured transformer was lower at all inductions. The ampere-turns required to excite the cube textured transformer to 17,000 gauss was approximately 50 pct of that required to produce the same induction in the grain oriented transformer.

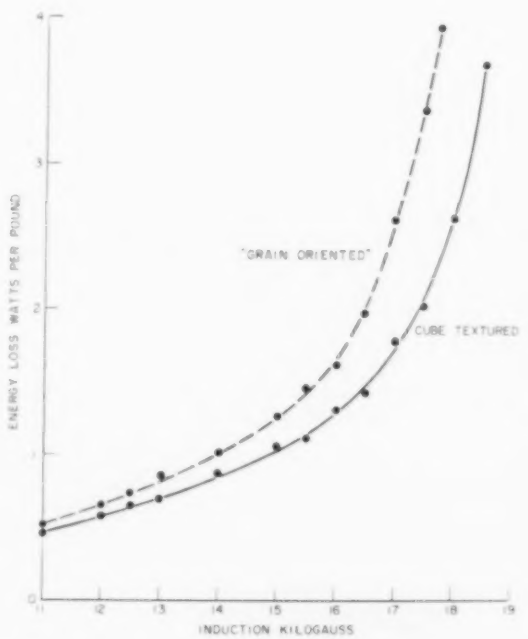


Fig. 1—Energy loss, in watts per lb, is plotted against induction for two transformers, one grain oriented and the other cube oriented.

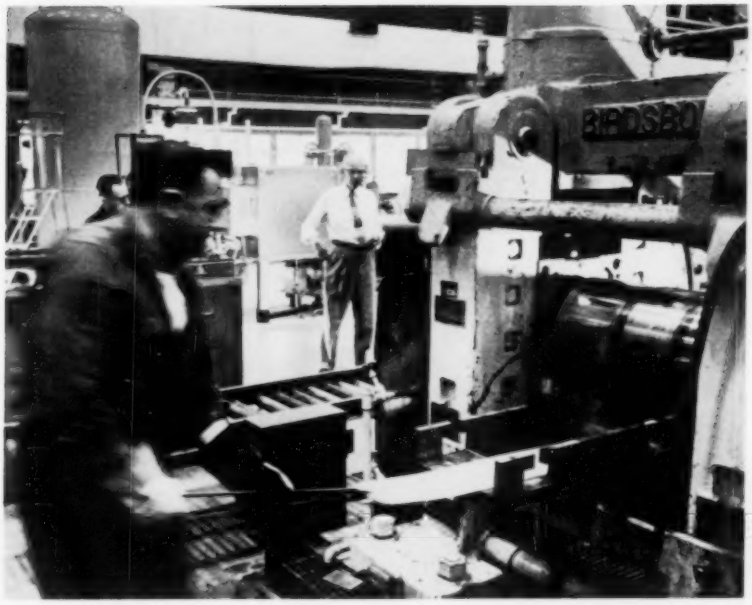


Fig. 2—Proper timing of the various processes, essential to production of cube oriented sheet, is studied at the General Electric Research Laboratory. Man in background is using a stopwatch while metal processor in foreground performs a rolling operation.

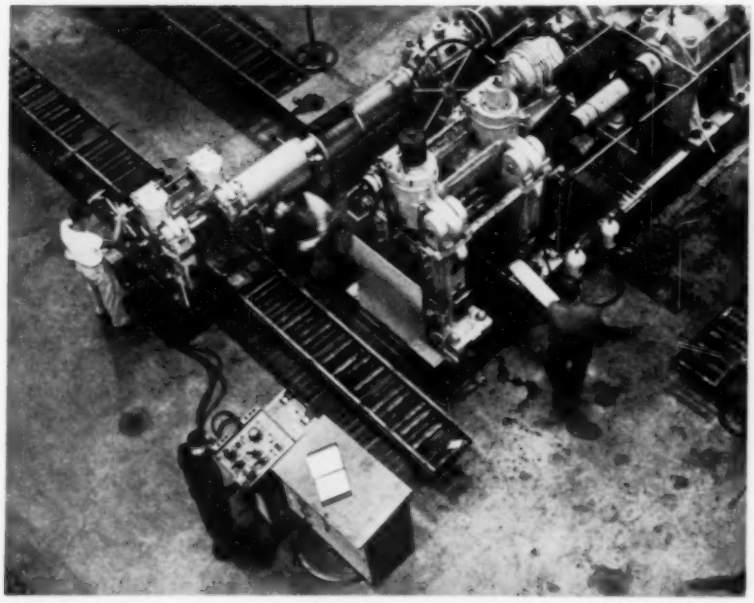


Fig. 3—Two rolling mills, at the General Electric Research Laboratory, perform successive rolling operations on cube oriented sheet. Operators must transfer the sheet from one mill to the other within narrow time limits.

Summary

Cube textured magnetic sheet containing approximately 3 pct Si in iron has been developed. The magnitude of the cube texture as determined by torque magnetometer tests is of the order of 90 pct or greater when compared to a single crystal with a (100)[001] orientation. The magnitude of the texture was confirmed by X-ray diffraction pole figures.

Static dc magnetic tests and 60 cycle ac watt loss tests made on single strip samples taken both parallel to the rolling direction and at right angles to the rolling direction indicate nearly equal magnetic properties in both directions of the sheet. These properties are equivalent to the magnetic properties measured in the single good direction of the grain oriented transformer material. Finally, two transformers were made: one using laminations of the cube textured silicon iron, the other of the grain oriented material. It was found that the transformer made of the cube textured material produced significantly lower energy losses at all inductions, and at 17,000 gauss the losses were approximately 60 pct of the losses produced by the grain oriented transformer. Similarly the current required to produce 17,000 gauss in the cube textured transformer was again about half that required to excite the grain oriented transformer to the same induction.

References

[1] Sixtus: *Physica*, 1935, vol. 6, p. 105.
[2] Bozorth and Williams: U. S. Patent 2,300,336 dated Oct. 27, 1942.
[3] C. G. Dunn: Private communication.
[4] Ackermann, et al.: *Tech. Mitt. Krupp*, 1957, vol. 15, p. 3.
[5] Möbius: German Patent 1,009,214 dated May 29, 1957.
[6] Assmus, et al.: *Z. Metallkunde*, 1957, vol. 48, p. 341.

HIGH-TEMPERATURE ALLOYS: 1900—1958

by F. S. Badger

From the early work on the gas turbine to today's efforts to obtain materials for service at over 2000°F, the processing of high-temperature alloys has been a tough, up-hill fight. The AIME High-Temperature Alloys Committee reviewed this progress at the Annual Meeting in February, and the JOURNAL OF METALS *here presents three of the papers from this session.*

ANY review of high-temperature alloys would be aided by tracing the parallel development of the gas turbine. This eventual prime mover was originally a simplified idea of the steam turbine principle, but was so limited by design problems and by available high-temperature materials that it was not until the 1900's that a gas turbine was constructed which had sufficient power to drive itself, let alone have any useful power left over.

Gas turbine was incentive

In this country, the early work of Sanford Moss on the gas turbine, starting in 1901 at Cornell University, eventually led to the development of the General Electric turbosupercharger. This device, first applied to aircraft engines by Rateau in France, was flown before the end of World War I. The US Army's interest resulted in Moss's concentration of his efforts on the aircraft supercharger in the period between the wars. The expense of this development at General Electric was borne by the Army from 1919 to 1937. It was the proving ground in this country for improved high-temperature materials, and placed this country in the forefront of high-temperature metallurgical development for three reasons: first, the Army's insistence on an American source for the alloys used in the supercharger; secondly, the high temperature of the exhaust gases of the reciprocating aircraft engines; and thirdly, the requirement of only hundreds of hours of useful life instead of a hundred thousand hours required for successful commercial applications.

F. S. BADGER is Vice President, Haynes Stellite Co., Div. of Union Carbide Corp. Paper presented at the AIME Annual Meeting, New York, 1958.

The most severe combination of stress and temperature in the turbosupercharger is met by the moving blades or buckets, even though the stationary nozzles are hotter and the wheels more heavily loaded. A chronological list of alloys used in General Electric supercharger buckets and the temperature at which they gave 100 hr rupture life at 20,000 psi is shown in Table I;[1] the analyses of these alloys are shown in Table II. Note the increasing chromium content of these alloys for improved oxidation resistance as the temperatures of operation are raised.

The change from iron-base to cobalt-base alloys and the change in fabrication from forgings to investment castings were responsible for the biggest jump, of 225°F, in operating temperatures in this sequence of alloys.

In 1936, the excellent high-temperature properties of the nickel-base Hastelloy alloys A and B were published, and the Army suggested the manufacturers contact General Electric with regard to the turbosupercharger application. This led to complete wheel and bucket assemblies of the 28 pct Mo "B" alloy which, although satisfactory strengthwise, oxidized on the edges of the buckets after long

Table I. Chronological Sequence of Bucket Alloys used in General Electric Turbosuperchargers and Temperatures for Rupture in 100 Hr at 20,000 psi

Years	Material	Original Use	Temperature for Indicated Rupture Strength	Form	Developed By
1918 to 1922	SAE 6150	Spring Steel	1050°F	Wrought	
1922 to 1928	Silchrome No. 1	Exhaust Values	1100°F	Wrought	Allegheny Ludlum Steel Co.
1928 to 1933	KE 965	Aircraft Exhaust Valves	1225°F	Wrought	Kayser and Ellison
1933 to 1942	17W	Turbo Buckets	1300°F	Wrought	Universal Cyclops Steel Co.
1942 to 1948	H.S. No. 21	Turbo Buckets	1525°F	Cast	Austenal Laboratories and Haynes Stellite Co.
1948 to Date	H.S. No. 34	Turbo Buckets	1550°F	Cast	General Electric Co. and Haynes Stellite Co.

Table II. Nominal Composition of Turbine Bucket Materials

Alloy	C	Mn	Si	Ni	Composition, Pct Cr	Co	Mo	W	V	Fe
SAE 6150	0.45	—	—	—	1.0	—	—	—	0.25	Rem.(98)
Silchrome No. 1	0.45	—	3.0	—	9.0	—	—	—	—	Rem.(87)
KE 965	0.45	0.6	0.6	14.0	14.0	—	—	2.5	—	Rem.(68)
17W	0.45	0.6	0.6	19.0	14.0	19.0	—	2.5	—	Rem.(42)
H.S. No. 21	0.25	0.7	0.7	2.5	27.0	64.8	5.5	—	—	2.0 max
H.S. No. 34	0.35	0.7	0.7	2.5	27.0	64.7	5.5	—	—	2.0 max

tests at 1500°F and above, due to lack of chromium in the composition. Also, the difficulties of forging and machining were excessive, although regarded as probably necessary in an alloy of the properties required. Consequently, General Electric continued work with Austenal Laboratories on investment casting buckets to finished airfoil shape, and at the same time with Haynes Stellite Co. on investment casting oversize buckets to be brought to size by forging in a single finishing die. To check out new tooling for the buckets, Austenal cast a few molds in their cobalt-base Vitallium denture alloy, and the castings looked so good that they were immediately tested out in a wheel and found to give outstanding service. Further tests demonstrated their excellent stress-rupture properties, but their low ductility led to reducing the carbon content from 0.50 to 0.30 pct, and this resulted in adequate ductility.

Age hardening proves troublesome

It appeared that the bucket problem was well on its way to solution until New Year's Eve, 1941, when a supercharger on test at Wright Field failed after 50 hr of test. The leading edges of the broken buckets were found to be as hard as R_c 62. The increase from the as-cast R_c 33-35 indicated excessive age hardening. Harried consultation led to modification of the alloy by increasing the nickel content from impurity level to 2.5 pct and specifying a maximum hardness of R_c 45 after 48 hr aging at 1475°F. This failure led to consideration of modified casting alloys, shown in Table III, which would have been used with some sacrifice of stress rupture life in case of a serious cobalt shortage. None was used in production except X-40, developed by General Electric. Later it was modified as Haynes Stellite No. 31. It was widely used by Westinghouse and is currently used for Pratt & Whitney J-57 engine buckets.

The attachment of buckets to wheels was too slow as a mechanical assembly for high production. Both manual welding and Unionmelt automatic welding were perfected. But the drawback was the tendency of the highly stressed welds between buckets to develop into cracks which spread into the wheel in service. This reduced the life of the assembly, but not beyond useful limits.

Advisory committee pushed research

Late in 1940, a group of metallurgists started meeting informally in Washington under the auspices of the National Advisory Committee for Aeronautics to discuss high-temperature alloys. In November 1941, this group was appointed the NACA Sub-Committee on Heat-Resisting Alloys. Because of the make-up of this Committee, its concern was primarily with wrought alloys, and it may be said that all of the improved wrought alloys, developed shortly thereafter by various sources, benefited by the combined experience of this group.

Table III. Nominal Composition of Casting Alloys Developed in 1941 and 1942

Alloy	Composition, Pct Cr	Mo	W	Ni	C	Co
61	28.0	—	6.0	2.0	0.45	64.0
6059	28.0	6.0	—	35.0	0.45	31.0
422-19	28.0	6.0	—	16.0	0.45	50.0
X-40	28.0	—	7.5	12.0	0.45	52.5

This committee is still active in the alloy field, and soon after its formation, the engine manufacturers and Government research agencies were included in its personnel. Lately, the name has been changed to the Sub-Committee for Power Plant Materials. This committee has been in a position to review and comment on the progress of the large volume of Government-sponsored high-temperature research.

The investment cast turbosupercharger buckets were at first used in forged 17W wheels in which the properties were improved by hot cold-work. Steel Improvement Co. was a major source of these forgings but experienced an unsatisfactory rejection rate. In 1942, this company made a trial forging of wheel blanks for General Electric of 16-25-6 alloy. This alloy was developed by Martin Fleischmann of Timken Roller Bearing Co. in 1941, for an Allis Chalmers turbine designed for the Navy. This trial was successful, as was the use of this alloy in the wheels of the turbosupercharger, and it was shortly adopted as standard. Within the period of one year the development of this alloy progressed from 35 lb experimental heats, to 1000 lb development heats in an arc furnace, and to 25 ton three-phase-arc production heats. It was strengthened both by 0.15 pct N, and by hot cold-work.

Turbojets draw attention

Aircraft gas turbine work in the US began with proposals from Northrop Aircraft, with the Turbodyne, and Lockheed Aircraft, with their L-1000, in the period from 1939-1941.[2] The NACA also developed the Campini Ducted Fan during this period. Pratt & Whitney at this time was working on the problem with Kalitinsky of M.I.T. In 1941, Turbo Engineering Co. started work for the Navy on a turboprop engine and on a small booster turbojet. Westinghouse also was at work developing the 19A turbojet, also for the Navy, and General Electric was developing the TG-100 at Schenectady. The work of the NACA Sub-Committee was soon concentrated on alloys for aircraft propulsion turbines.

It was later determined that work was started in Germany in 1936 on a turbojet engine designed for jet propulsion. Information on successful construction and flight of German jet propelled aircraft became available in the US early in 1942. The engine used was the Junkers 004, a short lived engine, probably suitable for only 10 to 40 hr flight time. Hollow buckets of deep-drawn Tinidur or formed and welded of Chromadur were used in production.

The analyses of these sheet alloys were as follows:

	Cr	Ni	Mn	Ti	Va	Si	N	C	Fe
Tinidur	15	30	0.7	2.0	—	0.8	—	<0.15	Bal
Chromadur	12	—	18.0	—	0.65	0.5	0.2	<0.12	Bal

In the Tinidur analysis, the titanium prevented satisfactory welding operations, and nickel was in critical supply in Germany, whereas the Chromadur contained no particularly critical elements and had good welding characteristics. However, its creep properties were definitely inferior to those of Tinidur. It is interesting to note that the Chromadur analysis is very similar to one on which a patent was granted in 1936 in the US to Becket and Franks.

In 1941, a General Electric turbosupercharger representative in England found that turbojet engines were being developed and about to be flown, and he brought this to the attention of the Air Corps. This led to a contract between the Army and the British on the one hand and the Army and General Electric on the other to build engines to the Whittle design. The contract was given to the turbosupercharger group of the General Electric Co. at Lynn, because of their successful turbosupercharger background.

General Electric determined that the turbojet buckets would run at a maximum temperature of about 1350°F, which was considerably cooler than the turbosupercharger buckets. They chose forged Hastelloy alloy B for the turbine buckets, since 1350°F was well within the satisfactory operating temperature for this alloy.[3] Despite, or perhaps because of, original excessively hot operation, this alloy proved superior to the British Rex 78 alloy and was designed into all the I-series centrifugal compressor engines. The I-40 was the first of these engines to be put into quantity production, and the alloys used were Inconel sheet in the combustion system, 16-25-6 in the turbine wheel, Hastelloy alloy B in the buckets, and investment-cast nozzles of Haynes alloy No. 21. Difficulties in forging the Hastelloy alloy B buckets in the quantities required led to part of Lynn's production being equipped with cast Haynes alloy No. 21 buckets, although casting techniques had still to be improved to make this bucket as satisfactory as the much smaller turbosupercharger buckets.

The history of the alloys used in the I-40 bucket, as the engine was redesigned for more and more output, is extremely interesting. The engine was the workhorse of the Korean conflict and is still being produced as the J-33 by Allison Div. of General Motors. The sequence of alloys is as follows: Hastelloy alloy B forgings, Haynes alloy No. 21 castings, S-816 alloy forgings, GMR 235 alloy castings, and other changes are still being evaluated. The competition between forgings and castings is evident, and the lower cost of castings appears to have had little effect on the choice of the method of producing this most critical part in the engine. In contrast, however, the investment cast nozzle has practically become the standard throughout the world, and cobalt-base cast alloys have been much preferred for this service because of their excellent heat-shock and corrosion resistance.

The use of 16-25-6 alloy wheels in the I-40 appeared successful, but after several thousand had been used, an occasional bursting showed up. This was found to be due to low center ductility and was overcome in three ways: first, by larger ingots and improved forging practices; second, by use of the Kellogg consumable-electrode melting process, giving cleaner, sounder center section material; and finally, by Unionmelt welding of 16-25-6 rims to a ferritic steel center section. The two latter solutions to the problem were used in General Electric's J-47 engine, and this engine utilized S-816 forged buckets throughout its production.

Afterburner needs special materials

In the efforts to develop increased thrust, outstanding was the afterburner which was even more dependent than the combustion chamber on high-temperature materials. Satisfactory wrought alloys are N-155 for general sheet construction and Haynes alloy No. 25 for the parts which are subjected to the highest temperatures.

A possible cobalt shortage led to much work on the development of nickel-base alloys strengthened with aluminum and titanium. Some of these alloys are Waspalloy, GMR 235, Hastelloy R-235, M 252, Udimet 500, and Inconel X. Their analyses are shown in Table IV.

Vacuum melting for scrap reclamation, close control

Waspalloy was employed extensively by Pratt & Whitney, but the scrap material could not be reused in the alloy and meet the specifications. Therefore, its accumulation represented a large stock of strategic material. It was determined that vacuum melting permitted the use of large quantities of this scrap, and by reduction of the oxides and other refinements, this gave material which would meet specifications. Utica Drop Forge acquired government equipment to perform this reclamation of scrap, and this represented the start of vacuum-induction-melting on a production basis. At an earlier date, considerable experimental work had been carried out on vacuum melting by Nisbet of General Electric with the idea of alloy improvement, but now the commercial push was given to this improved process of melting.

It was soon found that induction-vacuum-melting was a ready method for close control of important alloying elements, such as aluminum and titanium, and that such elements could be maintained at a higher level by this method of melting without adversely affecting cleanliness and hot-working properties. This was felt to be due to elimination of low melting, high vapor-pressure impurities, as well as to reduction of gas content and oxides and prevention of the forming of nitrides and carbonitrides. In general, stress rupture properties were improved as well as hot and cold ductility. However, inherent difficulties are present where very high vacuums are used. These include the vaporization of desirable elements, such as manganese and chromium, and the disintegration of the refractories by their reduction where high temperatures are also reached. Also sulfur, which is undesirable, is not removed by the process. These difficulties led to a complete change in vacuum melting philosophy, in that what might be called *dead melting* was employed using the purest premium raw materials and maintaining low molten-metal temperatures and short melting cycles, with little refining action except for that of the vacuum. This type of melting is less practical as regards its use of metals, since the recharging of scrap is held to a very low point, but it permits

Table IV. Nominal Composition of Nickel-Base High-Temperature Alloys

Alloy	Composition, Pct C	Mn	Si	Cr	Ni	Co	Mo	Ti	Al	Fe	B
Waspaloy Pratt & Whitney	0.05	0.7	0.4	19.0	58.0	14.0	3.0	2.5	1.3	1.25	—
GMR-235 Cast General Motors	0.15	0.1	0.3	15.5	65.0	—	5.3	2.0	3.0	10.0	0.05
Hastelloy alloy R-235 Haynes Stellite	0.13	0.5	0.5	15.5	66.0	1.5	5.5	2.5	2.0	10.0	—
M-252 General Electric	0.10	1.0	0.7	19.0	54.0	10.0	10.0	2.5	0.7	2.0	—
Udimet 500 Wrought Utica Drop Forge	0.12	0.5	—	20.0	59.0	18.0	4.0	3.0	2.75	1.0	—

greater output from available vacuum melting equipment.

One of the difficulties, which has plagued alloy producers, is the variation in high-temperature properties which, when specifications are set near the optimum for a given alloy, may show low or borderline physical tests when the chemical analysis is apparently under control. Work by Universal Cyclops on an Air Force sponsored project investigating the effect of incongruous elements on high-temperature properties gave a lead that boron and zirconium in small amounts are beneficial. Further work at Universal and the University of Michigan tied down these effects. Good practice in the use of refractories for melting has been realized to have desirable effects. It is now demonstrated that boron and zirconium are, under some circumstances, beneficial constituents of good refractories. Many of the super alloys have contained traces of one or the other, if not both, of these elements, and boron has been extensively used to improve high-temperature properties of many of the alloys developed by the Electro Metallurgical Co., div. of Union Carbide Corp.[4]

In the meantime, another method of vacuum melting had been brought to a high degree of practicality in the melting of titanium ingots. This is consumable-electrode vacuum-melting into a water-cooled copper ingot mold. It is somewhat similar to the Kellogg process with vacuum refinement added. This method was applied by Allegheny Ludlum to the super alloys, particularly in making large, sound ingots and wheel alloys, such as A-286. The analysis of this alloy, together with those of several other later wrought alloys, is shown in Table V. This type of melting generally leaves the metal molten and subject to the refining action of the vacuum for very short periods of time. Control of the size of the molten pool determines grain structure and central segregation. It is believed that the ultimate in refining action and large ingot structure is obtained by dual melting; that is, preparing highly refined electrodes melted and cast in the vacuum induction furnace for remelting in the consumable-electrode arc-furnace. This dual melting process yields good structure and freedom from segregation in the final ingots.

Current problems

Currently, engine builders are looking for a bucket alloy which will give a stress-rupture strength of 20,000 psi at 1800°F for 100 hr. A series of development alloys are reaching for this high figure by endeavoring to balance high tungsten or high aluminum and titanium contents against the minimum acceptable ductility. These alloys are all casting alloys, and the nickel-base alloys are presently developing 18,000 psi and a little higher under the desired conditions, but the best cobalt-base alloys are somewhat weaker. They are Udimet 500, vacuum remelted; WI-52; HDA 8294; Inco 713; and HDA 8151. Their nominal compositions are shown in Table VI. Necessary to the consistency of properties of these alloys is close control of aluminum, titanium, and boron, where present; this control is aided by vacuum melting. As the ultimate in high-temperature properties for these types of alloys is approached, the closest control of composition is essential. It is hoped that minor element additions, such as those of specific rare earths, may be found to further enhance their properties. However, it will be surprising if the useful operating temperature of these nickel-base and cobalt-base alloys is increased more than another 100°F, particularly since oxidation resistance at surface grain boundaries is an ever present problem with nickel-base high titanium and aluminum alloys. The Larsen-Miller diagrams for these new alloys in the region of particular interest are shown in Fig. 1.

With the cobalt-base and nickel-base bucket alloys approaching suitability for use at 1800°F and with little, if any, prospect of extending their usage beyond 1850 to 1900°F, the designers are crying for

Table V. Nominal Composition of Later Wrought Super Alloys

Alloy	Composition, Pct C	Mn	Si	Cr	Ni	Co	Mo	Ti	Al	Fe	Other
Discaloy 24 Westinghouse	.03	0.64	.92	13.1	25.5	—	2.83	1.83	0.16	55.0	—
A 286 Allegheny Ludlum	.05	1.35	.95	15.0	26.0	—	1.75	2.0	0.2	52.0	0.3V
G-18-B Wm. Jessops	.40	0.8	1.0	13.0	13.0	10.0	2.0	—	—	54.0	3.0Cb
16-15-6 Timken	.08	7.5	1.0	16.3	15.3	—	6.3	—	—	54.0	0.2N
Nimonic 80 Mond Nickel Co.	.05	0.7	0.5	20.0	76.0	—	—	2.3	1.0	0.5	—
Nimonic 90 Mond Nickel Co.	.05	0.7	0.5	19.5	55.0	18.0	—	2.5	1.4	2.0	—
Haynes Alloy No. 25 Haynes Stellite	.15	1.5	1.0	20.0	10.0	50.0	—	—	—	2.0	15.0W
Inconel X International Nickel	.08	.65	0.5	15.0	72.0	—	—	2.5	0.7	7.0	1.0Cb 0.2Cu

Table VI. Nominal Composition of Current Development Investment Casting High-Temperature Alloys

Alloy	Composition, Pct												
	C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	Ti	Al	Fe	B
WI-52 Tungsten Institute	0.4	0.3	0.3	19.5	1.0	68.0	—	11.0	1.5	—	—	0.5	0.09
H.D.A. 8294 Haynes Stellite	.01	0.1	0.1	15.0	73.5	—	5.0	—	—	—	6.7	—	—
Inco 713 International Nickel	.15	1.0	0.3	12.5	73.0	—	4.5	—	2.0	.75	6.0	0.3	—
Udimet 500 Cast Utica Drop Forge	.07	0.1	0.3	18.0	63.5	18.0	4.5	—	—	3.0	3.0	0.5	—
H.D.A. 8151 Haynes Stellite	0.5	0.6	0.6	20.0	—	66.0	—	12.5	—	—	—	—	0.05
GMR-235D General Motors	.15	.05	.15	15.5	70.0	—	5.5	—	—	2.3	3.5	4.3	0.08

bucket temperatures of 2000°F and up. It has long been evident that a radically different approach is necessary to supply alloys to meet this higher temperature range desired in gas turbine operations. Also, the high Mach number requirements of ramjets, of very high speed aircraft, and, of missiles during the period of reentry, extend the temperature demands upon materials up to and above the melting points of most existing alloys. So, we now have an entirely new measuring stick in the development of high-temperature materials, and we are going to have to develop super high-temperature alloys. Here work is being concentrated on the high melting point metals: tungsten, tantalum, columbium, molybdenum, and their alloys. Since these metals are both refractory and reactive, they are difficult to process.

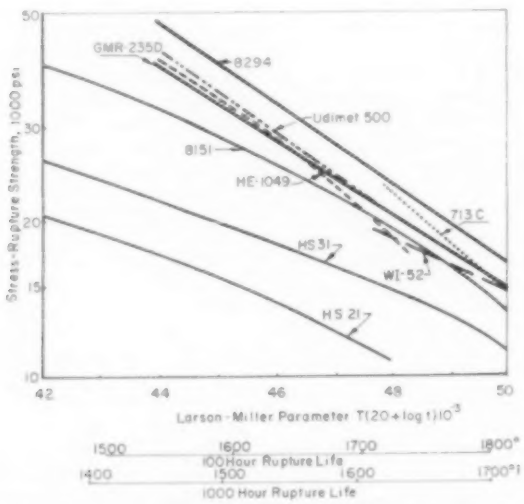


Fig. 1—The Larsen-Miller diagrams for new high-temperature alloys in the region of particular interest.

Molybdenum, being in a further state of development than the other refractory metals because of the work of Climax Molybdenum and Westinghouse, has been the furthest advanced of this group and has had extensive Government support. With respect to oxidation resistance, however, these alloys are inferior to the old alloys. In the temperature range from 2000 to 2400°F, the oxidation resistance of the old alloys is inadequate for long service, but the new reactive-metal-base alloys are particularly poor in this respect. It is proving more difficult to develop good oxidation resistance than high strength at these high-temperature ranges. Except for short periods of exposure, it now seems that metal cladding or refractory coating will be necessary to adequately protect these new alloys from oxidation. This adds to the weight and makes high surface finish more difficult.

These difficulties lead us to the consideration of new types of high-temperature materials: the ceramics, metal ceramics, and high-temperature compounds fabricated by powder techniques. Included in these is the incorporation of refractory oxides throughout metal and alloy bodies, the well-known SAP techniques still to be worked out for high alloys. The work of N. J. Grant et al on dispersed hard-particle strengthening of metals dramatically increases the creep strength of nickel and molybdenum.[5] However, this class of material is currently handicapped by low impact-strength and ductility.

Let us now take a hasty look at a few of the special methods of melting which may in the future be developed to a point of practical utility in the high-temperature field. Zone melting and its related cage melting are very useful for refinement of pure metals, particularly silicon, but this does not currently appear applicable to high-temperature alloys because of the varying partition coefficients of the alloying elements. Electron beam melting is receiving a great deal of attention with the entry of Temescal into this field. This method looks very promising for producing ingots of the very high melting point metals and alloys, because of the amount of power which can be delivered at a high rate.

In closing, let us draw attention to three areas where progress is essential in pushing back the high-temperature frontier. First is improved refractories for induction vacuum melting. Second is new oxidation-resistant refractory alloys, or else practical methods of surface coating of these alloys for life adequate to their required uses. Third is the requirement for impact resistance and ductility in ceramics, metal ceramics, and compounds.

While extensive work is being devoted to these problems, progress at the moment is all too slow and the need for solution is becoming increasingly urgent.

References

[1] I. Perlmutter: High Performance Jet Engine Design Dependent Upon Metallurgical Ingenuity. JOURNAL OF METALS, vol. 6, no. 2, Feb. 1954.

[2] R. Schlaifer and S. D. Herron: Development of Aircraft Engines and Aviation Fuels. Published by Harvard University Graduate School of Business Administration, 1950. Much of the historical background in this paper has been derived from this book.

[3] F. S. Badger, Jr. and W. O. Sweeney, Jr.: Metallurgy of High Temperature Alloys Used on Current Gas Turbine Designs. A.S.T.M. Symposium on Gas Turbines. Forty-Ninth Annual Meeting, Buffalo, New York, June 1946.

[4] U.S. Patent No. 2,562,854 (W. O. Binder).

[5] N. J. Grant and O. Preston: Dispersed Hard Particle Strengthening of Metals. JOURNAL OF METALS, vol. 9, No. 3, Mar. 1957.

SLIP CASTING

by L. M. Schifferli, Jr.

THIS method of making shapes from high-temperature materials is not only practical and economical, but in many cases, it is the only method for preparing certain useful shapes from many high-temperature metals and materials. Briefly, slip casting is a process for making shapes which consists of dispersing finely powdered materials in a fluid, and then pouring such stable suspensions into absorbent molds. After removal from molds and drying, shapes so produced are sintered at elevated temperatures to increase density and strength.

A slip may be thought of as a viscous liquid containing any finely divided solid in stable suspension. Besides the solid and liquid phases, which must be chemically non-reactive, a third phase, a dispersing or deflocculating agent, is generally needed to act as a stabilizer to prevent agglomeration or rapid settling of the powdered solid phase. Slips are really complex colloidal suspensions rather than mere slurries or muds. As such, they possess rather unusual rheological properties.

Nature of the process

While there are certain similarities between casting slips and casting molten metals, it might be well at this time to note some of the important differences. Molten metals solidify in molds by a freezing operation accompanied by a small volume contraction which can cause shrinkage in the casting. Slips, on the other hand, solidify by removal of the suspending media, usually by absorbent plaster molds. While a good slip usually has a very high per cent of solids by weight, the volume of the solids is relatively low, anywhere from 20 to 60 pct, and, hence, volume shrinkage of the suspension during casting is relatively large. Gating problems are, therefore, more acute for slip casting than for casting from the molten state. Another very important difference is the temperature involved. Casting molten metal naturally involves temperatures in excess of the melting point of the metal or alloy under consideration. Slip casting, however, is accomplished at room temperature or slightly above. A comparison of mold life for the two methods shows the plaster molds for slip casting may be used as many as 50 to 80 times. Another very important difference between casting molten metals and slips is the strength of the resulting casting. Depending upon metal temperature and mold temperature, a metal casting generally consists of a strong, coarse-grained structure capable of withstanding considerable mechanical abuse. On the other hand, a slip-cast shape upon removal from the mold is found to be relatively fragile, fine grained, and of a relatively low density. Such shapes must be subjected to a sintering or a firing operation before they are useful. Slip casting, on the other hand, is analogous to conventional metal casting in that both processes involve the three fundamental operations of pattern making, mold preparation, and founding.

L. M. SCHIFFERLI, JR., is Staff Development Engineer, Haynes Stellite Co., Div. of Union Carbide Corp., Kokomo, Ind. Paper presented at the AIME Annual Meeting, New York, February 1958.

Advantages and disadvantages

Perhaps the outstanding advantage of the slip-casting process is its ability to produce shapes from certain classes of materials which could be produced by no other process; for example, such a useful material is a combination of chromium metal and aluminum oxide. This material has good oxidation resistance, adequate thermal shock resistance, and appreciable strength at temperatures at which most ferrous alloys are molten. Such a combination of materials as chromium and aluminum oxide obviously cannot be melted and cast in the conventional metallurgical sense, because of gross separation of the two phases in the molten condition. While simple geometric shapes of limited sizes can be made from this material by cold pressing in steel dies, production of large shapes would be prohibitively expensive because of die costs.

The slip-casting process has certain inherent disadvantages. Fragility in the green state necessitates extreme care in handling. Strength and other desirable mechanical and physical properties can be developed in slip-cast shapes only by a sintering process. Because of the fine-grained nature of the casting and because of its low density, considerable shrinkage is normally encountered during this sintering operation. Large percentages of shrinkage commonly cause some distortion or cracking. Precise particle size distribution control is essential for dimensional reproducibility. Control of particle size distribution is difficult, especially with the fine, subsieve powders needed for the successful operation of this process.

Steps in slip casting

Figures 1 through 4 illustrate schematically the various operations pertinent to the slip casting process. The hypothetical shape shown in Fig. 1 could be readily slip cast, but could not be economically prepared by more conventional powder metallurgical processes, such as pressing or extrusion. This illustrative shape was chosen to show use of a split plaster mold, in addition to both drain and cored casting techniques.

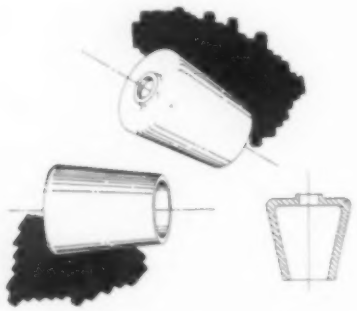


Fig. 1—A representative shape which can be readily slip cast, but would be difficult and expensive to cast by other processes.

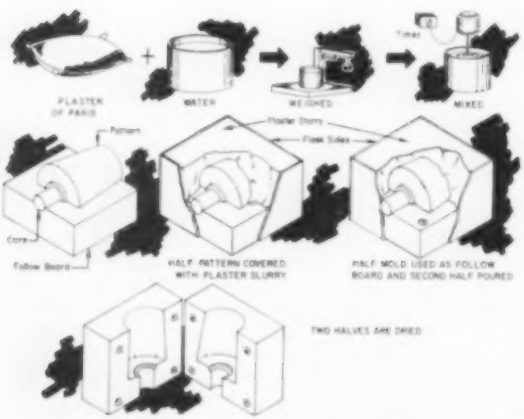


Fig. 2—Steps involved in making the mold prior to slip casting.

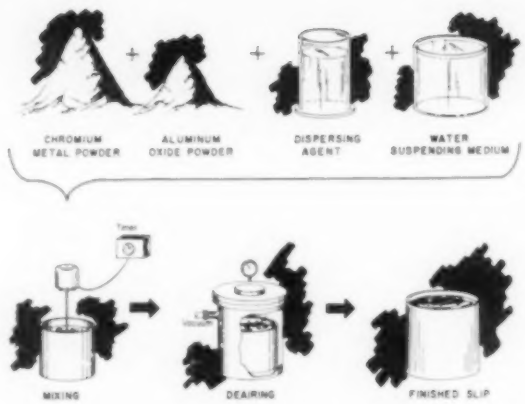


Fig. 3—Steps in the preparation of the slip.

For mold making, two ingredients, plaster of Paris and water, are required. Plaster of Paris is a hemihydrate of calcium sulfate. When this material is mixed with water, in excess of stoichiometric requirements, the hemihydrate is converted to the bihydrate (gypsum). Drying removes the excess water, and a strong, porous material results. To insure some measure of control, both ingredients should be at room temperature and both should be weighed accurately. Mixing time should also be uniform from batch to batch to insure molds with reproducible porosity or absorption. In the example illustrated, a solid pattern which can be of any material capable of taking a smooth surface, such as wood or metal, is seen to have a reversed taper which necessitates a split mold. In order to make molds which will be split evenly, a follow board is used. The wooden sides are then placed around the pattern, and the plaster slurry is poured over it. Properly mixed plaster will set quite rapidly and some heat is generated because of the reaction between the plaster and water. This heat is generated after the plaster has received an initial set. At this time, the flask may be removed, and the first mold half may be removed from the pattern and follow board. Using the pattern and the first mold half just formed as a follow board, a flask is again prepared by placing sides around it, and an additional quantity of plaster slurry is poured over it. To prevent the two halves of the plaster sticking together, a thin parting compound such as soap, vaseline, or oil may be used. Multiple piece molds, especially relatively long ones, should be securely clamped together during the drying process to prevent warpage. More complete details of plaster mold making may be secured from plaster manufacturers. Plaster mold making is somewhat of an art and, in this case especially, experience is the best teacher. Mold characteristics which are important to the process are strength, porosity or absorption, surface condition, service life, and ease of release of casting.

The slip-making process utilizes three materials: a finely comminuted solid, a liquid suspending agent, and normally, an additive which helps to maintain a stable suspension. The liquid and the additives are usually premixed prior to the addition of the solid phase, which is added slowly and with

constant mixing. The mixing operation is very important, and again controlled timing should be used to insure reproducible slip properties. Any mixer which will produce a large amount of shear may be used for this mixing operation. During this mixing operation, a large amount of air is normally entrapped in the slip and, in order to produce a casting free from pinholes, this is normally removed by means of de-airing. When properly prepared, this slip will be quite fluid, and the suspended solids will have little tendency to settle upon standing.

Fig. 4 illustrates the slip-casting process itself, and again it is shown in relation to the same mold shown in Fig. 2. The two halves of the dried mold are clamped securely together, the nonabsorbent core is inserted, and the mold is filled with slip. Care should be taken to incorporate as little air as possible during this initial casting operation. As soon as the slip contacts the absorbent plaster molds, a solidification against the mold walls ensues. The mold now acts both as a sponge and as a filter; it absorbs the liquid suspending media from the slip by capillary action, while the suspended solids build up against the interior mold walls. When the sufficient wall section has built up against the mold sides, the mold is simply inverted and the excess liquid slip is drained. Adcock and McDowall[1] critically review the casting process for clay base materials and conclude that the mechanism is simple dewatering. After a short period of time, during which the mold continues to absorb some of the water remaining in the solid casting, it will be noticed that a small amount of drying shrinkage in the mold has occurred. This is evidenced by a very slight pulling away of the casting from the mold sides. At this point, the core is removed, and the two mold halves may be separated to reveal the final casting. Trimming of part lines or other minor repairs can be made on the casting at this time. After appropriate drying, which may be either in air or in a forced convection dryer, the casting is ready to be sintered.

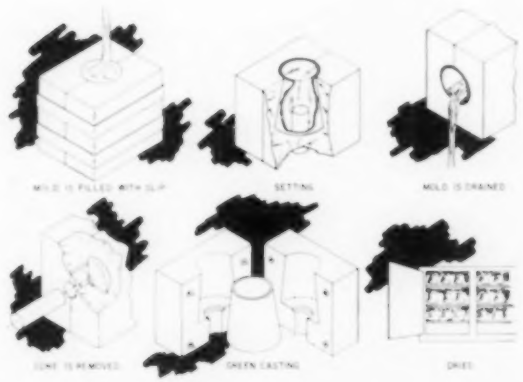


Fig. 4—Steps in casting the slip, removal, and drying.

Effect of variables

Since the various characteristics of the three ingredients of a slip can be controlled, at least to a greater or lesser extent, the resultant slip properties can also be controlled.

The following criteria are useful for evaluating the slip-casting process.

Casting time: The time required for a slip to set up in a plaster mold to produce a green object of a given size and shape may be called its casting rate. A slip with a rapid casting rate usually on the order of 1 to 3 min is undesirable for the fabrication of complex objects with varying cross sectional thickness. On the other hand, a slip with a slow casting rate, for example, over 30 min, is also objectionable, since excessive set-up time reduces production per mold. Slips with casting times of 10 to 30 min are generally best suited to forming the majority of slip-cast articles, either drained or solid.

Casting surface: Surface finish of a green slip-cast object is usually closely associated with the casting time of the slip. A slip with a very rapid casting rate usually produces a rather granular finish, characterized by concentric lines on the surface. Usually longitudinal lines, or pouring marks, roughly equivalent to cold shot in metals, are also present where the slip contacts the sides of the mold during the pouring operation. Such markings are obviously objectionable, not only because of the poor finish produced, but also because they may act as stress risers or planes of weakness in the fired shape. Slow casting slips usually produce a fine-grained surface with a definite sheen, free of any markings.

Casting shrinkage: This shrinkage is beneficial, since it facilitates the removal of the casting from the mold. On the other hand, excessive casting shrinkage is equally undesirable, since stresses may then arise which would cause cracks or tears. Fast casting slips generally show little or no shrinkage and have quite a tendency to adhere to the plaster mold.

Green Density: It is important that the castings, when dried, have a good density, since upon this depends high green strength, low porosity, and low firing shrinkage. This particular property is extremely important to the overall success of the slip-casting operation. In common with the other criteria listed as useful in the evaluation of slips, this property is a function of powder particle size, proper mixing techniques, and suitable dispersing agents.

Slip casting ceramics

Slip casting of clay-base ceramic shapes depends almost entirely upon the unique properties of naturally occurring clays and clay-like minerals, such as kaolinite. These minerals are found in nature as extremely small hexagonal plates which may be as small as $\frac{1}{2}\ \mu$ across corners and about one tenth of this in thickness. When clay is added to water, the viscosity of the mixture will increase rapidly with increasing solids content until a thick, slimey paste results. The addition of deflocculating agents, such as a mixture of sodium carbonate and sodium silicate, will produce a remarkable change in the physical characteristics of the mixture; what started out as a thick, gummy paste is now a fluid with a very low viscosity. Clay particles have absorbed a charge from the electrolyte used, probably through a double ion layer, and, consequently, they repel each other. The particles are now highly dispersed and viscosity drastically reduced. Settling is impeded because of Brownium movement and, in such a condition, Stokes Law is not operable.[2]

The technique of slip casting has also been applied to such non-plastic ceramic oxides as alumina, thoria, beryllia, and magnesia. Since these materials do not occur in nature in a sufficiently finely divided state, the required fine particles must be obtained artificially. This can be accomplished in the case of oxides which do not react with water by ball milling in either steel or ceramic lined mills for periods of time sufficient to reduce the average particle size to the order of a few microns. Suitable powders for slip casting can also be prepared by low temperature calcination of chemically precipitated hydroxides or other methods. These oxides are readily dispersed in water and an acid electrolyte is normally used as an additive to produce the necessary charge on the particles to induce deflocculation and retard settling.[3]

Slip casting metal-ceramic combinations

Currently, three types of metal ceramic combinations are in an advanced development stage or pilot plant production. These proprietary compositions[4] are shown in Table I. Each has been slip cast and sintered in quantity into a variety of sizes and shapes.

Table I. Compositions of Three Metal Ceramics

Material	Wt. Pct		
	LT-1	LT-1B	LT-2
Chromium	77	59	25
Molybdenum	—	20	—
Tungsten	—	—	60
Aluminum Oxide	23	19	15
Titanium Dioxide	—	2	—

Note: All compositions have about 65 vol pct metallic phase.

Aluminum oxide is the ceramic material common to all three of these combinations. This oxide is prepared by calcining an aluminum trihydrate to remove water followed by an acid bleaching and washing step to reduce soda content. This alumina has a surface area of approximately 30 to 50 sq m per g with an ultimate average particle size of about 0.3 μ. The powder is, however, loosely agglomerated into much larger individual particles. Chromium metal is also an ingredient common to all three materials. This is a commercially available electrolytic grade of chromium metal which has been ball milled to a −325 mesh powder, with an average particle size of about 5 μ as determined by the Fisher Sub-Sieve Size method. Both the molybdenum and tungsten metal powders are hydrogen reduced and have average particle sizes of about 2 to 5 μ. Again, they are commercially available from several sources. In the preparation of a slip of LT-1, for example, water and an electrolyte (dilute mineral acid) are added to the mixer initially. The aluminum oxide powder is gradually added during the high-speed mixing stage. The resulting colloidal suspension of alumina contains about 60 pct solids by weight. After dilution, the chromium metal powder is gradually added, again with constant mixing. Some of the chromium metal powder particles are too large to receive an adequate electrical charge. Upon standing, however, these particles have little tendency to settle from the suspension, since they are buoyed up by the highly dispersed alumina phase. It is to these suspensions of chromium metal and aluminum oxide that either molybdenum or tungsten metal powder is added to prepare the other two materials. In the case of the latter two metal powders, they must be added to the prepared chromium-alumina suspension quite slowly in order to prevent an agglomeration of this suspension. Addition of dilute gum arabic solutions may be helpful in preventing flocculation.

Solid content of these slips is well over 80 pct by weight; viscosity, while it is naturally appreciably higher than water, is such that efficient drain casting is possible with the slips. As a matter of fact, the majority of the shapes produced were drain cast shapes, although slips with these properties allow preparation of both solid and cored castings as well. Upon extended standing, the solids in these slips do settle to some extent. However, no preferential settling has been encountered. That is, a column of slip after drying showed the same chromium metal/alumina oxide ratio from the bottom to the top. Any settling which does occur can be readily redispersed by mixing. The shelf life of these particular compositions is virtually indefinite, providing precautions against excessive evaporation are observed. The colloidal nature of these materials is not lost during drying, and, hence, any unsintered scrap may be immediately reused. The economic implications of this are obvious. The drain casting operation is exactly as discussed previously.

Sintering as a physical and chemical phenomenon is extremely complex, and numerous theories have been proposed to delineate the true nature of the sintering mechanism.[5] It may be sufficient to say that the loose bonds, which hold the dried shape together, are strengthened during sintering until low porosity materials result. The materials shown in Table I are sintered in an inert atmosphere (argon and hydrogen) at temperatures between 2850° and 3100°F. It should be mentioned that, while an appreciable shrinkage or contraction of the shape occurs during this sintering operation, the relative dimensions of the shape remain unchanged.

Typical mechanical properties of these three metal ceramic combinations are shown in Table II.

The modulus of elasticity shows only a slight decrease in the 70° to 1800°F range. It will be noted, the strengths referred to are transverse or cross bending strengths (modulus of rupture), which is the commonly accepted method of measuring brittle materials. The first two compositions retain appreciable fractions of their room temperature strength at temperatures as high as 2400°F. Only limited transverse strength data on the high tungsten content material were obtained because of its relatively poor oxidation resistance. These data do show, however, only a slight decrease in strength with temperatures up to 2200°F. Thus, these materials retain appreciable strength at temperatures considerably in excess of the maximum usable operating temperatures of ordinary high-temperature alloys.

Table III shows typical physical properties of these three metal ceramic materials. Since all three contain a continuous metal matrix (65 pct by volume), they are relatively good conductors of both heat and electricity. Although they are brittle, their thermal shock resistance is generally more than adequate for most applications. No specific data on this property are given, however, because there is, at present, no one standard accepted method of measuring it. Since all three of these materials contain appreciable quantities of chromium metal as well as the inert aluminum oxide, their oxidation

Table II. Typical Mechanical Properties of Sintered Metal Ceramics

Property	LT-1	LT-1B	LT-2
Modulus of Elasticity, psi at 70°F	37.5×10^6	28×10^6	38×10^6
Modulus of Elasticity, psi at 1800°F	33×10^6	31×10^6	33×10^6
Transverse Strength, psi at 70°F	45,000	56,000	73,000
Transverse Strength, psi at 1800°F	26,500	54,600	—
Transverse Strength, psi at 2100°F	16,600	29,000	—
Transverse Strength, psi at 2400°F	4,600	11,800	—
Compressive Strength, psi at 70°F	111,000	240,000	—
Sintering Temperature, °F	2850	2850	3050
Max Service Temp, °F	2500* 3000†	2800	3100‡

* Continuous Service, † Short Time Service, ‡ Reducing Atmosphere.

resistance is good. Values of oxidation resistance at 2200°F compare very favorably with commercially available nickel-base alloys. However, the material containing tungsten is considerably poorer than the other two, as might be expected.

While numerous large-volume commercial applications for these materials have not yet been found, the chromium-aluminum oxide combination has proved to be an outstandingly good thermocouple protection tube material. It has found widespread use in both the brass and steel industries where it is used to temperatures in excess of 2400°F. Intermittent, short time use over 3000°F has been reported from immersion pyrometry applications. Its combination of good thermal conductivity, high strength, low oxidation resistance, and good corrosion resistance against molten copper-based alloys as well as to hot flue gases makes it an outstanding material. Performance of both LT-1B and LT-2 as nozzles used with solid fuel propellants indicated the superiority of these materials over a wide number of other compositions tested. Details of this test evaluation may be found in an Armour Research Foundation Project No. G-030 report.

Tolerances usually encountered with these three materials are about ±3 pct of a blueprint dimension. However, closer dimensional tolerances than the cast and sintered shape can be met, since these materials are readily machinable. All three materials have been subjected to the various operations, such as threading, turning, grinding, boring, and milling. Because of the relatively high hardness and brittle nature of the material, low feed rates and speeds must normally be used.

Comparison with other fabricating methods

The big advantage of the slip casting over other methods of fabrication for materials similar to those discussed lies in its relative ease and low cost. For example, in cold pressing, expensive hardened steel or tungsten carbide dies are necessary and a large number of pieces must be made to offset this without excessive costs. In addition to these dies, a hydraulic press is also necessary. Naturally, the size of this hydraulic press must be in proportion to the area of the piece desired. For most powdered materials, pressures of at least 10 tons per sq in. are needed to affect sufficient green strength and density for handling. Thus, for a piece about 10 in. square, a press of over 1000 tons capacity would be needed. Such shapes, however, are readily slip cast without the need for either steel dies or high-capacity presses.

Table III. Typical Physical Properties of Sintered Metal Ceramics

Property	LT-1	LT-1B	LT-2
Apparent Density, lb per cu in.	0.21	0.22	0.32
Theoretical Density, pct	95	92	91
Water Absorption, pct	0.03	0.02	0.17
Apparent Porosity, pct	0.19	0.15	1.50
Hardness, Rc	37	50	52
Thermal Expansion, in. per in. per F°, 77 to 1832°F	4.95×10^{-6}	4.71×10^{-6}	4.64×10^{-6}
Elec. Resistivity, Microhm-Cm at 70°F	80	65	46
Oxidation Resistance, at 2200°F, 100 hr, Continuous, IPY	0.165	0.095	37.5
Oxidation Resistance, at 2200°F, 100 hr, Intermittent, IPY	0.131	0.159	231.0

Slip casting would probably not be competitive with cold pressing, if a large volume of pieces of relatively simple geometry were required. High speed, multiple-acting presses are commercially available and can produce up to several hundred pieces per hour from powdered metallic materials. Hot pressing, the simultaneous application of both heat and pressure to a powdered substance, is another method used for the fabrication of shapes from high-temperature materials. It does offer a rapid method of producing shapes of limited geometry, which have good physical and mechanical properties. Besides the limitations briefly discussed under cold pressing, hot pressing has one other disadvantage. The most universally accepted mold for hot pressing is graphite. Because of this, the hot pressing method can only be used with materials which do not react chemically with carbon at elevated temperatures. Size and shape limitations, which apply to the cold pressing method, also apply to hot pressing, although unit pressures involved are normally much lower than those used for cold pressing. Induction heating of the graphite die is one method of attaining the requisite sintering temperatures.

Another fabrication method, which is sometimes applied to the production of shapes from powdered materials, is extrusion. This involves the incorporation of a binder, usually a combination of organic materials into the powdered material to impart both plasticity and lubricity. The artificially plasticized mass can then be extruded into simple geometric shapes by means of an extrusion press. After drying, such shapes are fired to remove the binder and to improve strength. In general, shapes that can be extruded can also be fabricated by the slip casting technique. Extrusion would be less expensive than slip casting, if the quantity of solid shapes or open end tubing would warrant investment in an extrusion press.

Slip casting as a fabrication method is a highly versatile one which can be applied to a wide variety of materials. The technique is relatively easy to apply and requires a minimum of capital investment in equipment. While a large number of factors enter into the process, and while all the fundamental, scientific details germane to the process have not been delineated here, it can nevertheless be applied to producing shapes from many useful high-temperature materials.

References

[1] D. S. Adcock and I. D. McDowall: The Mechanism of Filter Pressing and Slip Casting, *Journal*, American Ceramic Society, vol. 40, no. 10, pp. 355-362, October, 1957.

[2] F. H. Norton: *Elements of Ceramics*, Addison-Wesley Press, Inc., Cambridge, Mass., 1952, Ch. 10, 11.

[3] W. D. Kingery, Editor: *Ceramic Fabrication Processes*, New York, Technology Press of Massachusetts Institute of Technology, and John Wiley and Sons, 1958, Part 1, Ch. 3.

[4] LT-1 U.S. Patent No. 2,698,990, January 11, 1955.
LT-2 U.S. Patent No. 2,656,596, October 27, 1953.
LT-1B U.S. Patent No. 2,783,530, March 5, 1957.

[5] I. E. Campbell, Editor: *High-Temperature Technology*, John Wiley and Sons, Inc., New York, 1956, Ch. 11.

VACUUM MELTING IMPROVES INVESTMENT CASTING

by J. A. Miller

INVESTMENT casting, or lost wax, process has been used to produce parts from high-temperature alloys for a number of years. The investment casting business expanded rapidly with the advent of the turbojet engine and the need for the production of many thousands of parts, such as turbine buckets, vanes, and aircraft hardware. The process lends itself to the economical production of parts of complex configuration from hard-to-work alloys.

In the past few years vacuum melting has been developed to provide improved properties and qualities in high-temperature wrought alloys. It was logical to combine vacuum-melting and investment-casting techniques to benefit from the advantages of both processes and to produce castings of superior quality.

Vacuum-melted alloy, which is to be investment cast, is prepared as a master heat weighing from 800 to 1500 lb. The furnaces used for the production of these heats are shown in Fig. 1. These units employ induction melting and operate at pressures of less than 100 μ Hg. Each furnace is capable of producing a 1500-lb heat every 5 hr, which is cast in the form of bars suitable for remelting. These bars are 2¼ in. in diam by 42 in. long. They are cast in thoroughly dry, dense, refractory sleeves. A special pouring basin is used during the tapping of the heat to improve the cleanliness of the bars.

Fig. 1—Vacuum furnaces used to produce master alloy which is later remelted and investment cast.

High-purity raw materials are used in the vacuum furnace charge; after these raw materials have been melted, they are refined at low pressure. During refining, a boil occurs as the result of the combination of carbon and oxygen in the molten bath to form carbon monoxide. The boil deoxidizes the heat by the carbon-oxygen reaction and removes other gases from the bath through the flushing action of the escaping bubbles. This boil coupled with the low pressures produces heats of low gas content. During refining, elements such as lead, tin, zinc, and bismuth, which vaporize readily, are removed from the bath to give a higher purity alloy. Formation of oxides and nitrides during melting and pouring is inhibited, since the partial pressure of oxygen and nitrogen in the furnace is extremely low as compared to a normal atmosphere. Chemical composition, particularly aluminum, titanium, and boron contents, may be more closely controlled during vacuum-melting than during melting in air. Little oxygen is present to form oxides of these elements and cause their loss. Special techniques are used in melting to prevent chemical segregation in the remelt bars.

Importance of master heat

It is beneficial both from the standpoint of quality and economics to produce the alloy as a master heat. The chemical composition and mechanical properties

J. A. MILLER is with Development and Technical Services, Haynes Stellite Co., Div. of Union Carbide Corp., Kokomo, Ind. Paper presented at the AIME Annual Meeting, New York, 1958.

of each heat are determined prior to its release for producing castings. This insures having acceptable quality alloy in the castings. Since the alloy has been previously refined, the time in the casting furnace may be shortened, thus achieving increased production and economies in the foundry. No alloying elements or deoxidizers need to be added to the alloy during remelting for casting. Fewer chemical analyses and mechanical tests of the castings are required, since the quality of the master heat has been previously established.

Two methods of remelting and casting vacuum-melted alloys are currently in use; these are vacuum-casting and controlled-atmosphere casting. Both methods of casting are based on the premise that the properties of the vacuum-melted alloy are developed in the master heat; during remelting and casting, the alloy is protected to preserve those properties.

Vacuum Process

The production of precision castings in vacuum is now a commercial process. A bank of vacuum-casting furnaces is shown in Fig. 2. These furnaces were designed especially to handle investment molds. Each unit is composed of four basic parts: the vacuum pumping system, the electrical power source and control panel, the induction furnace, and the vacuum shell.

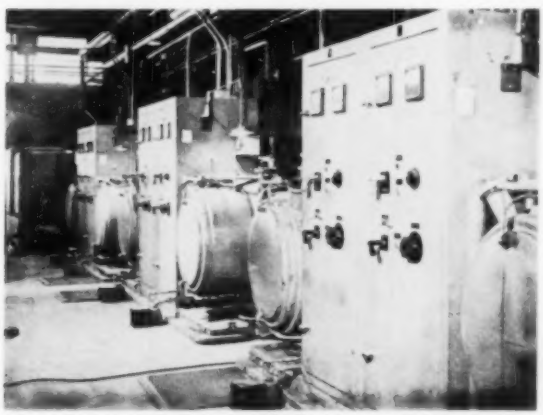


Fig. 2—Vacuum furnaces used for investment casting.

The pumping system consists of a mechanical, roughing pump, and an oil-diffusion pump to attain high vacuum. Pressure in the vacuum system is monitored by means of a Piranni gauge. A leak rate of less than 50 μ per hr is maintained on a cold furnace.

One mold is cast during each furnace cycle. This mode of operation is felt to give optimum control of the alloy and quality of the casting. Furnace cycles vary from 15 to 30 min, depending on the weight of alloy being melted. Pressure in the furnace during melting and casting is maintained below 10 μ.

Controlled atmosphere process

In controlled atmosphere casting, the induction furnace is not enclosed in a shell as in vacuum casting. However, the interior of the tightly covered furnace is maintained under a positive pressure of inert gas while the melt is in the furnace. When the melt is ready to pour, a hot investment mold, which has had the mold cavity flushed with inert gas, is clamped on top of the furnace with gate of the mold over the furnace crucible, as shown in Fig. 3. The furnace and mold are inverted, and the alloy passes from the furnace to the mold without being exposed to the air.

Fig. 3—Furnace used for controlled-atmosphere casting. An investment mold is clamped in place on the furnace, which is inverted to fill the mold.

Results of vacuum investment casting

Investment casting of vacuum-melted alloys has been limited, primarily, to the casting of high-temperature alloys known to be benefited by vacuum melting. These are the titanium and/or aluminum bearing, nickel-base alloys. These alloys are GMR-235, GMR-235D, Udimet 500, Haynes Development alloy 8294, and Waspalloy. All of the alloys except Waspalloy have been vacuum-cast. Investment-castings of GMR-235, GMR-235D, and Waspalloy have been produced using the controlled-atmosphere method of melting and casting.

These alloys exhibit excellent stress-rupture properties. Fig. 4 shows typical stress-rupture

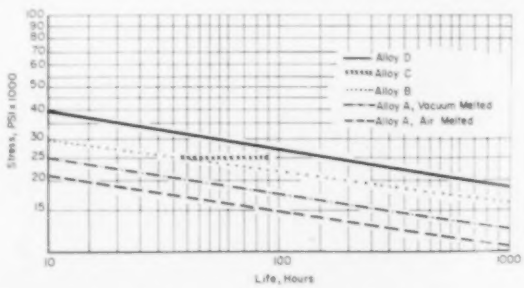


Fig. 4—Stress-rupture curves for vacuum melted, vacuum investment cast alloys at 1700°F. Alloy A, GMR-235; Alloy B, GMR-235D; Alloy C, Udimet 500; and Alloy D, Haynes Development Alloy 8294.

curves obtained at 1700°F. The increase in stress-rupture life of vacuum-melted, vacuum-cast GMR-235 may be seen in comparison to the same alloy which was air-melted and controlled-atmosphere cast.

Experimental work has indicated little improvement in stress-rupture life to be gained by the vacuum melting of cobalt-base alloys for investment casting. The rupture life of vacuum-melted investment cast Haynes 31 was found to be erratic. The variation observed from heat to heat was not resolved. Work at the Aviation Gas Turbine Div. of the Westinghouse Corp. indicated no increase in rupture life for Haynes 31 or Haynes HE1049, but did show increased stress-rupture ductility for the vacuum-melted alloy.

It appears that each alloy must be thought of as an individual when the effect of vacuum-melting and vacuum-casting on mechanical properties is considered. Sufficient evidence is not available to allow general conclusions to be formed covering all alloys. However, the existing data indicate that alloys of improved high-temperature properties are being produced by this method.

Problems with vacuum casting

Although improvements have been attained by vacuum casting, the price of operation in vacuum must be paid. Since a high vacuum must be obtained before the alloy is melted, the furnace cycle is longer than in conventional casting; this increases foundry costs.

Constant attention is required to maintain leak rates on the vacuum system at the lowest possible level. Cleanliness is of prime importance, particularly, for vacuum seals. One particle of grit may be sufficient to cause an excessive leak. Specially-trained people and high cost equipment are necessary to detect leaks when they do occur.

Moisture in the vacuum system is a problem. Atmospheric moisture accumulates in the oil of the vacuum pumps and must be removed to allow satisfactory pump operation. Drying of a newly rammed furnace is difficult. Oven drying is beneficial, but is not sufficient. Several wash heats are normally made in vacuum before the furnace is considered to be completely dry. The slightest water leak in the induction coil or water leads of the furnace is very detrimental and must be located and corrected immediately. Many times these leaks are so small that they are not visible.

Furnace refractories also present a problem. Pouring temperatures are often quite low in vacuum casting and a skull or layer of metal remains in the furnace crucible after pouring. Removal of this skull causes deterioration of the refractories. Any patching material which is used must contain the least possible amount of moisture.

Vacuum casting requires greater care and skill on the part of the casting operator than does conventional casting. The operators must be carefully trained and close supervision of the operation is required.

Advantages

A number of advantages of vacuum casting may be contrasted against the disadvantages of operating in a high vacuum. Close control of chemical composition and improvement of high-temperature properties are obtainable by vacuum casting. In addition, during vacuum casting the alloy is protected from contamination by gases which are present in the normal atmosphere. Dissolved gases are maintained at low levels. Formation of nitride and carbo-nitrides is largely eliminated. The surface of the alloy in the casting furnace appears bright and free from oxide scum. The alloy is clean as it enters the mold and produces castings free from *dirt-type* defects.

The mold is thoroughly degassed before pouring. The elimination of back pressure from gas trapped in the mold by the entering alloy allows castings of thin cross section to be poured at temperatures considerably lower than would normally be possible when gravity-pouring in air. Freedom from oxide scum on the surface of the alloy has allowed close control of pouring temperatures to be attained with optical pyrometers. The use of low, closely controlled pouring temperatures has allowed turbine blades, having cast-to-size airfoil sections, to be produced *with small grain size throughout* from nickel-base alloys. These blades, which are about 5 in. in length and have a maximum thickness of about 3/8-in. in the base, are being produced in commercial quantities to have a maximum size of less than 1/16-in. diam in all sections. Normally, the grain size is much smaller than this in the airfoil section of the blade. The grain size in the airfoil of a Udimet 500 alloy blade ranged from ASTM No. 4 to No. 1 with some grains as large as 1/32-in. diam in the thicker portion of the airfoil. Those familiar with the grain size of investment castings know that grains may be quite large. It would not be uncommon to have grains 1/2 to 3/4-in. diam in a blade of this size cast by usual methods. It is expected that the small uniform grain size obtained in these blades will give improved fatigue properties and better response to heat-treatment.

The application of vacuum melting to investment casting has resulted in the production of superior quality castings. Improved high-temperature properties have been attained. Parts of complex configuration are produced with excellent surfaces that require little or no machining. The size of the casting is controlled to close dimensional tolerances, and the castings are free from gas porosity, shrinkage, and excessive non-metallic inclusions. Grain size is controlled to be uniformly small to give improved properties. The future of the high quality, precision casting produced in vacuum appears bright.

References

[1] R. K. McKechnie, D. W. Green, W. F. Moore: Some Observations on Vacuum Metallurgy, Electric Furnace Steel Proceedings, *AIME*, 1954.

[2] J. H. Moore: Vacuum Melting—Its Promises and Problems, Electric Furnace Steel Proceedings, *AIME*, 1954.

[3] H. R. Spendelow, Jr., I. S. Servi, and G. A. Fritzlen: Vacuum Melting of High-Alloy Materials, *Vacuum Metallurgy*, The Electrochemical Society, 1954.

[4] F. K. Iverson: Bright Future Seen for Vacuum Investment Castings, *The Iron Age*, vol. 178, No. 3, p. 20, July 19, 1956.

[5] M. J. Stutzman: Studies and Comparison of the Properties of High Temperature Alloys Melted and Precision Cast Both in Air and Vacuum, Westinghouse Electric Corp., Report No. A-2429Z, Summary Technical Report, USAF Contract No. AF 33 (616)-3468, Project No. 7351, December 26, 1957.

Hot Top Practice at Lukens Steel

Significant savings have been affected through in-plant production of cement hot tops.

By R. L. Bunting, Jr.

BECAUSE of the many different-sized molds needed and the varying demand for different size ingots, hot top costs, supply, and inventory were once a problem. In an attempt to solve this problem, the possibility of producing hot top molds was investigated. The investigation was started in 1947, and by 1949, a Hot Top Dept. had been organized and was supplying the open hearth demands for tops. Today, with few exceptions, all tops used by the open hearth are produced by the Hot Top Dept. Fire-clay-brick tops are laid by the bricklayers when the ingot height is less than 12 in. from the top of the mold.

Fig. 1—Mix is shoveled into the pattern box and rammed; man in background is placing ¼-in. reinforcing wire on top of the first course of sand.

Production of cement hot top molds

The cement top is composed of high purity silica sand (95 pct SiO_2), high early portland cement, and ¼ in. reinforcing wire. The particle size of the sand is critical and must meet the following specifications by Standard Sieve Analysis: 5-15 pct, 20 to 30 mesh; 8-16 pct, 100 mesh or less; and the remainder 40 to 70 mesh.

Sand and cement in the ratio of 7:1 are mixed in a small 1000 lb muller. A complete cycle, charge to charge, takes 5 min. Sand and cement are charged in the muller with a scoop truck and mixed for 1 min. Water, equal in weight to 5 to 6½ pct of the sand cement charge, is added to the charge at the end of 1 min and the mixing is continued for 2 min. In cold weather, the lesser amount of water is used and 1-2 lb of CaCl per bag of cement is added to the mix. Moisture and grain size must be controlled to prevent slumping of the green top.

At the work site, the mix is shoveled into a pattern box and rammed with pneumatic hammers. Several inches of sand are shoveled into the pattern box, the sand is rammed, and ¼ in. reinforcing wires are placed on top of the sand. More sand is shoveled into the pattern box and the operations are repeated until the sand is 3 to 4 in. from the top of the box. This operation is illustrated in Fig. 1. Wires are tamped into the rammed mix vertically, and the box is filled completely with the mix. The mix is rammed and smoothed off flush with the top to the pattern box.

Two cores in the pattern leave holes in the ends of the tops. Tops are lifted with hooks or a special sliding bar inserted in the holes. After the top is set in a mold, the holes are plugged with a cement core. These holes can be seen in the tops in Fig. 1.

Immediately after the mix has been rammed and smoothed off, the pattern box is stripped. This operation is shown in Fig. 2. The core is stripped, the outside box is removed, and the pattern is lifted away from the cement top. The pattern box is assembled next to the stripped top and is ready to be used to make another top.

The cement top is corrugated to conform to the sides of the mold wall. The patterns are made by the Carpenter Shop and are treated with paraffin or oil to facilitate the stripping operation.

The inside edges of the top are beveled manually after the pattern box has been removed. This bev-

Fig. 2—Men are here shown stripping the core from a 70 x 30 x 22 in. top.

R. L. BUNTING, JR., is with the Metallurgy Dept., Lukens Steel Co., Coatesville, Pa. Paper presented at the National Open Hearth Conference, Cleveland, April 1958.

eled edge is the bottom of the top when the top is set in the mold. When hot metal rises against the beveled edge of the top, the metal will not push the top out of the mold.

The top remains on the floor for a 24 to 36 hr curing period. At the end of the curing period, the top is turned over and the beveled edge is dipped in a core wash. The core wash fills the pores and provides a smooth surface on the bottom of the hot top mold. The top is stored in the hot top department for a total time of 72 to 96 hr from the time it is stripped. No forced drying methods are used to cure the top. An area of 33,600 sq ft is necessary for the production and storage of the hot tops needed to meet the production demands of the Open Hearth.

Use of cement tops

The tops are stored in the Hot Top Dept. until they are needed in the open hearth pit. When the pit is set, tops are transferred on narrow gage flat cars to the pit area.

In the pit, the tops are carried with a special sliding-bar-hook. The special hooks provide a safe method for lifting the tops. Also, when the sliding bar is used, top breakage is reduced. Top breakage from all causes is less than 3 pct. Approximately 2 pct of the tops are broken in transportation from the Hot Top Dept and 1 pct are broken in handling operations. Fig. 3 is a picture of a sliding bar.

Two practices are used to set the tops in the mold. 1) Ingot molds which have a cross section of 70 x 23 in. or larger are lined with a feather-edge. It is made of fire clay brick and mortar and is held in place with steel straps. Fire clay is spread on top of the feather-edge to seal the top to the feather-edge.

The strap length is determined by the height of metal needed in a given size mold to make the ordered ingot weight. Because of the large number of different size plates produced by Lukens, the weights of ingots will vary for a given size mold. The cement top has sufficient strength to hold hot metal even when it protrudes above the top of the ingot, but a steel band is placed around the top for safety.

2) Ingot molds with a cross section smaller than 70 x 23 in. are not lined with a feather-edge. The top is set directly on steel strap-hangers.

All cement tops are held down in the molds by wooden wedges which are placed between the top and the mold. This practice is satisfactory and top fly-ups do not occur frequently.

To prevent collars, teeming is stopped for 45 sec when the hot metal reaches the bottom of the hot top. Teeming is stopped two more times before the top is completely full. This practice, particularly when a feather-edge is used, prevents the formation of collars or metal breakouts through the plugged holes in the end of the top.

When the top is full, Mexatop is thrown on the metal and spread to form a uniform insulating blanket over the metal. In Fig. 4 you can see the Mexatop and straw spread over the hot top. The straw is placed in the bottom of the mold before the ingot is teemed. Straw prevents metal splash on the mold wall and provides an insulating blanket over the metal while it is rising in the mold. The floating straw will usually catch spalls or dirt falling into the mold.

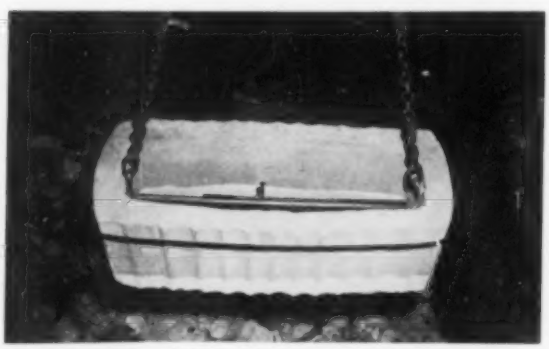


Fig. 3—Sliding bar used to lift the hot tops in the open hearth pit.

Fig. 4—Mexatop and straw, which act as an insulating blanket and keep out dirt, on top of a full hot top.

Advantages of cement hot top practice

1) Hot top mold inventory is held to a minimum: Top inventory would be a large expense if tops were purchased from outside suppliers. A large inventory would be necessary to meet the fluctuating demand for different size ingots. The Hot Top Dept. can supply tops to the open hearth in a minimum time of six days. When the demand increases for certain size ingots, the Hot Top Dept. is notified of the requirement and schedules their production to meet the demand. This advantage can not be realized when tops are supplied by an outside supplier.

2) The volume of solidified metal in a cement top varies between 8.5 and 15 pct of the ingot weight, the larger volume applying to larger ingots. Of course, the amount of metal remaining in the cement top depends on the amount of metal poured in the mold. However, metal savings as great as 3 pct of the ingot weight were realized when the cement top replaced clay brick tops.

3) The cement top is a good insulator. The metal remains molten for a longer time than it does in other tops that have been used in our shop. Mexatop insulates the top exposed metal of the hot top and feed-back of hot metal is excellent.

4) Cost per top, delivered to the open hearth pit, is less for the cement top than it is for any other top.

5) The top is easily removed from the ingot: The cement top mixture readily breaks away from the ingot when the ingot is stripped.

6) The top does not spall when it is exposed to hot metal or heat.

HIGH-GRADE IRON ORE AT COPPER CLIFF, ONTARIO

by Paul Queneau, E. H. Bracken, and Daniel Kelly

High iron content of nickel concentrates produced at Copper Cliff, Ontario, Canada has been a controlling factor in nickel smelting capacity. Solution to the problem has been achieved by separating an iron concentrate of low nickel and sulfur content, with virtual elimination of copper, precious metals, and silicates.

ORE milled by The International Nickel Co. of Canada, Ltd. in the Sudbury District of Ontario, Canada consists essentially of pentlandite, nickeliferous pyrrhotite, chalcopyrite, and rock minerals. Until recent years, the sulfide minerals were recovered by flotation in a mixed pentlandite-pyrrhotite nickel concentrate and a copper concentrate. Since the iron:nickel ratio of the nickel concentrate was approximately 10:1, the controlling factor in nickel smelting capacity was the large quantity of iron to be slagged. Studies on separate treatment of the nickeliferous pyrrhotite concentrate for iron recovery indicated that this could be achieved on a satisfactory basis through development of economical procedures whereby: a) the nickel content of the concentrate could be reduced to below 1.0 pct with accompanying virtual elimination of copper, precious metals, and silicate contamination; b) the sulfur content of the concentrate could be reduced to below 1.0 pct, while producing a gas having a sulfur dioxide content of 10 pct or more; and c) the nickel content of the resulting iron oxide could be reduced to 0.15 pct or less. The first of these requirements was met many years ago, but it was not until 1954 that the development of procedures to meet the second and third requirements was sufficiently advanced to justify a commercial operation. Development of the Inco Iron Ore Recovery Process in laboratory and pilot plant has been discussed in an earlier paper.[1]

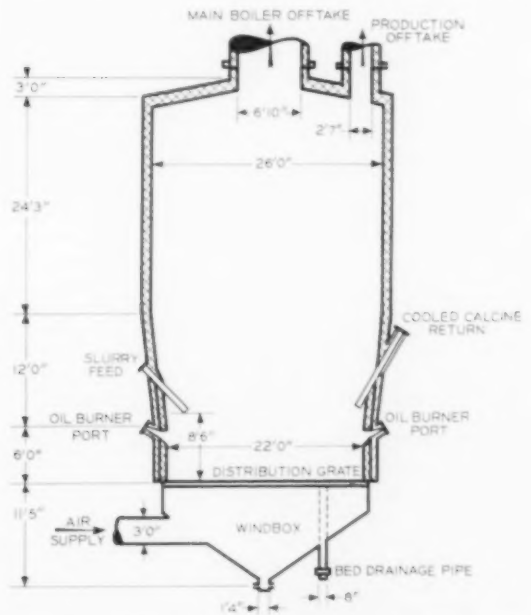


Fig. 1—This 550 tpd fluid bed roaster is used for dead roasting pyrrhotite concentrate at Copper Cliff, Ontario, Canada.

A $20 million plant for separate treatment of 365,000 tons per year of pyrrhotite by the new process was constructed near Copper Cliff, Ontario, Canada, and its operation started early in 1956. It is the first unit of an installation which will have a capacity of more than 1,000,000 tons per year of pyrrhotite. Sulfur elimination is accomplished in fluid bed roasters, operating in closed circuit with cooling boilers and cyclones.[2] Nickel is extracted by atmospheric pressure leaching in ammoniacal solutions, following selective reduction of the calcine in kilns using concurrent gas-solids flow.[3] Permanent magnet drum separators are used for thickening in the countercurrent leaching operation, and steam kettles are employed for nickel precipitation from pregnant solution. The magnetite fines are agglomerated into 1-in. balls by pelletizing on discs and firing on a travelling grate.[4]

Pyrrhotite concentrate

Pyrrhotite concentrate is produced in the Copper Cliff mill by a sequence of beneficiation operations, which include grinding, flotation, magnetic separa-

PAUL QUENEAU, E. H. BRACKEN, and DANIEL KELLY are with the International Nickel Co. of Canada, Ltd., as Asst. Vice President, and Superintendent and Asst. Superintendent, Iron Ore Recovery Plant, respectively.

This paper was presented at the 1958 Annual Meeting

tion, regrinding, and reflotation. The resulting product contains 0.05 pct Cu, 0.75 pct Ni, 57 pct Fe, 37 pct S, 2.5 pct SiO_2, and is about 90 pct through 200 mesh. Part of the nickel is present as a very fine dispersion of pentlandite in the pyrrhotite, and the remainder as a solid solution in the latter mineral.

The concentrate is pumped as a 20 pct solids pulp through wood-stave pipes 4 mi to the Iron Ore Recovery Plant, west of Copper Cliff. Here it is dewatered to 75 pct solids in two 35x12 ft thickeners, which are in the open and have a capacity of 1000 tpd of pyrrhotite each. Accurate control of underflow solids content is assisted by radio-isotope pulp density recorder-controllers. The underflow is pumped to two, 340-ton capacity mechanically agitated storage tanks with air-lift circulation. Wilfley pumps, with Ni-Hard impellers and follower plates, are used for transmission of the abrasive, high-density pyrrhotite pulp. An effective feed system was developed to provide the uniform pulp flow rate at constant density essential to good roaster performance. The pulp from the storage tanks is pumped to a small, constant-head, agitated tank located beside the roaster and above the feed points. Gravity flow from the tank is regulated by compressing or releasing a bottom-located rubber orifice and thus changing its aperture. The so-controlled pyrrhotite supply falls to a four-way distributor and is carried to the roaster by rubber pipe lines.

Control of desulfurizing

Roasting is the first major unit operation in the conversion of finely-divided, nickel and sulfur-bearing iron ore into lump, low-nickel, sulfur-free iron ore. Upon dead roasting, the pyrrhotite (Fe_7S_8) is essentially oxidized to hematite. The nickel originally present in pentlandite and in solid solution in pyrrhotite reports mainly as a nickel ferrite.

Roaster capacity is favored by operation at temperatures above 1500°F, but this should be avoided since otherwise calcine activity in the subsequent reduction and leaching operations may be adversely affected. Roaster capacity is favored by production of a calcine containing more than 0.25 pct sulfide sulfur, but this should be avoided, since nickel as sulfide dissolves in the leaching section at a slower rate than as ferronickel and gives rise to undesirable sulfur compounds in the ammoniacal solution. Roasting is carried out at about 1450°F, and oxygen supply is so controlled that a small amount of magnetite is produced in a ratio of about 1 Fe_3O_4:10 Fe_2O_3. In this manner the oxygen content of the outlet gas is kept below 0.5 pct, while producing an active calcine.

The roasters

Roasting is carried out in two 550 tpd fluid-bed roasters. The sulfur content of the calcine amounts to 0.5 pct, about one-half sulfide sulfur and the balance sulfate sulfur, and the sulfur dioxide content of roaster outlet gas is 13.5 pct, dry basis, approximately the theoretical maximum. This represents a capacity greater than that of any other known roaster now in service.

In the novel Inco fluid-bed roasting process all of the calcine is withdrawn from the top of the roaster through two different sized outlets operating in parallel, each with its own dust recovery system. Production calcine leaves the roaster through the smaller outlet, the dust laden gas passing through small diameter cyclones which discharge their catch at roaster temperature to the reduction kiln. Circulation calcine leaves the roaster through the large central outlet, the dust laden gas—normally in a volume about five times that exhausted through the production calcine outlet—passing through a boiler for cooling and large diameter cyclones which discharge their catch back into the roaster. The Dorr concept[5] of feeding concentrate to fluid bed roasters as a water slurry is employed.

The roaster, of joint Inco-Lurgi design, is a refractory lined, cylindrical steel shell, see Fig. 1. The bottom 12 ft of refractory consists of 9 in. of firebrick, backed with 4½ in. of insulating firebrick. The remainder of the shaft is lined with 9 in. of 2000°F insulating firebrick.

The roaster shell, flue system, cyclones, boilers, and Cottrells are externally insulated with 3 in. of mineral wool to keep steel temperature at roughly 500°F, to avoid acid condensation.

The Lurgi grate is made up of mild steel bars bolted tightly together with tapered slots between them for air flow. The grate weighs 20 tons and is securely held to a metal framework supported by the cone-shaped windbox. The open area of the grate is approximately 0.5 pct, which gives a 1 psi pressure drop with air flow at about 1300 tpd for a 500 tpd pyrrhotite feed rate.

Fig. 2—Interior of rotary kiln for selective reduction of calcine at Copper Cliff, Ontario, plant of International Nickel Co.

Fluid bed roasting

Relatively coarse 65-mesh to 20-mesh particles, provided by natural occurrence in the pyrrhotite feed, maintain a bed on the grate to a depth of 3 ft when in repose. The bed material is fine enough to fluidize readily, but too coarse to be carried up the wider diameter upper section of the shaft. Shaft gas velocity, 3.5 fps, is in excess of the terminal settling velocity of the calcine.

Four oil burners inclined 15° downward, equally spaced around the shaft and 6 ft above the grate, are used for initial heating preparatory to introduction of the pyrrhotite and its autogenous roasting. During the heat-up period, the air blast is turned on for a few seconds every 2 min to insure uniform heating of bed and shaft. Twelve hours of

heating are required to bring roaster temperature up to about 1300°F.

At the end of the heating cycle, the oil burners are withdrawn and pyrrhotite pulp is fed at full flow to four water-jacketed 1½-in. diam, stainless steel guns inclined 60° downward and discharging 8.5 ft above the grate. The required air blast is then applied, and the roaster roars swiftly and smoothly to life. Its temperature rises to about 1450°F throughout the shaft. Recording-controlling instrumentation of solid, liquid, and air input automatically maintains the fluid bed and the dust suspension above it at a temperature within 25°F of target.

Gas leaving the roaster by the production outlet passes through refractory-lined cyclones and well over 90 pct of its dust burden is collected and fed by gravity directly to the kiln below. The gas is then cooled to 800°F in a small Lamont forced-circulation boiler, drawn through a variable speed fan and discharged to the Cottrell for recovery of its residual dust content.

Calcine and gas leaving the roaster by the circulation outlet are cooled in a two-pass Lamont forced-circulation boiler. Operating steam pressure is 550 psig so as to maintain the 1¼-in. carbon steel tube temperature safely above the dew point of sulfuric acid. The tubes are hung vertically in panels and the abrasive dust-laden gas travels parallel to them. Transport of 2500 tpd of calcine through the boiler without undue tube erosion requires special design measures. Steam production per roaster at a 500 tpd pyrrhotite feed rate is about 55,000 lb per hr, of which 50,000 lb is generated in the main boiler, corresponding to 1.3 lb of steam per lb of pyrrhotite. More than half of the calcine carried by the gas entering the main boiler drops out between passes and returns by gravity to the roaster. The boiler exit gas is relieved of over 80 pct of its remaining dust burden by passage through mild steel cyclones, the catch returning by gravity to the roaster and the gas passing to the Cottrell. Precipitator dust is fed to the reduction kiln.

Dust precipitation

Each roaster is served by a Research-Cottrell electrostatic dust precipitator which removes 99.7 pct of suspended matter from 90,000 cfm of gas at 700°F. The Cottrell inlet gas dust loading of up to 20 grains per cu ft is reduced to 0.05 grains per cu ft at the outlet. The precipitator is equipped with corrugated steel collection plates, dual wire discharge electrodes, and a high intensity rapping system. Energizing by vacuum tube rectifiers at 75 KV and 50 KV and sequential rapping of electrodes without interruption in power supply makes the operation entirely automatic. The precipitator is two units wide and four sections long. It provides a treatment length of 32 ft, a treatment time of about 8 sec and a gas velocity of 4 fps.

The exit gas analyzes about 12 pct SO_2 and 1.5 pct O_2, dry basis. A substantial fraction of this gas is employed as feed stock for the adjacent new 350 tpd acid plant, of Canadian Industries Ltd. A portion of the gas will be subjected to T.G.S. catalytic reduction with hydrocarbons in the adjacent Texas Gulf Sulphur Co. 10 tpd sulfur recovery pilot plant, now under construction. The balance of the gas is exhausted to atmosphere 637 ft above ground level through a reinforced concrete chimney.

Reduction of nickel

Each of the fluid bed roaster systems is in gravity feed relationship to a rotary kiln; the Roaster-Kiln building, thus, contains two complete units in duplicate for the dead roasting of pyrrhotite and selective reduction of the resulting calcine preparatory to leaching. A properly conducted roasting operation oxidizes most of the pyrrhotite's nickel content and the residual sulfide nickel must be dealt with in the leaching operation.

The function of the reduction operation is to convert the oxide compounds of nickel in kiln feed to the ammonia-soluble metallic state. This task is complicated by the reaction between the oxides involved. Since Ni^{++} can replace Fe^{++} in both Fe_3O_4 and FeO, these iron oxides can prevent a considerable proportion of the nickel from being reduced. Reduction of nickel to the metallic state results in the formation of a nickel-iron alloy of variable composition. Although the equilibrium reduction potential of the kiln gas does not permit formation of pure iron, nickel takes iron into solid solution and thereby facilitates reduction of iron oxides. It is important to avoid a low ratio of nickel to iron in this ferronickel, since this causes difficulties in leaching.

The novel Inco concurrent flow selective reduction process allows a successful compromise between excessive nickel loss in substituted magnetite and excessive iron recovery in ferronickel. The first reduction stage of the kiln operation is at relatively high temperature, 1600° to 1650°F, and in a strongly reducing atmosphere which limits the formation of $(FeNi)_3O_4$. Most of the oxide nickel is converted to a nickel-iron alloy, and the remainder reports in the iron oxides. The final reduction stage of the kiln operation is at relatively low temperature, 1200° to 1300°F, and in a selectively reducing atmosphere having a CO_2:CO ratio of about 2.5. Thus, as the ore moves slowly down the kiln it reaches conditions under which (FeNi)O is unstable and decomposes to Fe_3O_4 with release of nickel as ferronickel.

Rotary kiln chosen

A rotary kiln was chosen for the reduction operation in preference to a multiple-hearth rabble furnace for reasons of gas-solid contact, capacity, simplicity, and safety, and in preference to a fluid bed furnace because of the slow selective reduction reaction. The kiln is 185 ft long, made gas tight by Lurgi water-cooled end seals, has a diameter inside the steel shell of 13 ft and is supported at a 3 pct slope by two riding rolls. This is the largest known gaseous reduction kiln in the world. It was supplied by F. L. Smidth and is of joint Inco-Smidth-Lurgi design, Fig. 2.

The last 20 ft of the kiln are devoted to ore cooling which is accomplished in a Smidth peripheral air-cooled cylinder cluster. Firing is concurrent using Bunker "C" oil and a Balcke high-pressure oil burner mounted in an ignition muffle supported by the feed end seal. Oil is preheated to 240°F, pumped at 500 psig to the burner and consumed at the rate of 250 gal per hr. Burner air is preheated to 600°F by heat exchange with kiln exhaust gas. Kiln speed is normally 0.8 rpm. Kiln refractory lining is 11½ in. thick, consisting of 9 in. of heavy duty firebrick backed by 2½ in. of Moler insulating brick. Four alloy steel 18-in. retaining dams give the ore a 6-hr avg retention time in the kiln and are located

along its length at 57 ft, 86 ft, 119 ft, and 160 ft, respectively from the feed end. Effective gas-solid contact is provided by alloy steel lifters 1 ft in depth, which start 10 ft from the feed end and extend 75 ft down the kiln.

Roaster calcine enters the kiln at 1000°F and is rapidly raised to a temperature of 1600°F by the oil flame. The difficult task of satisfactory, rapid partial combustion of the heavy oil and avoidance of undue formation of carbon black during cracking is aided by the shower of hot calcine. Controlled conditions of kiln temperature and gas analysis are maintained to produce the desired selectively reducing atmosphere. Oil combustion is regulated in respect to both quantity and oil:air ratio so that gas at the discharge end of the kiln has a temperature of about 1250°F and a CO_2:CO ratio of about 2.5. Indicated oil consumption amounts to 3,000,000 Btu per long ton of iron ore pellets. Kiln atmosphere is maintained at a positive pressure of about 1.5 in. W.G.

The kiln coolers discharge the calcine, now essentially magnetite with a little wustite, ferronickel, and nickel-iron sulfide, at 400°F directly into one of the two agitated water quench tanks provided each kiln. The magnetite pulp is pumped at 30 pct solids to the Leaching building. Kiln exhaust gas is cleaned by passage through refractory-lined cyclones. Dust collected is discharged to the water quench tank and the cleaned gas passed through a shell-and-tube heat exchanger for cooling by kiln burner air as noted above. The cooled gas exits to a variable speed fan which controls kiln pressure with the aid of a butterfly damper. Fan discharge passes to an oil-fired furnace for burning of residual combustibles including carbon. The hot furnace gas exhausts into the main flue system and assists in maintaining an over-all waste gas temperature adequate for its satisfactory atmospheric diffusion and dispersal.

Leaching metallics and sulfides

Reduced calcine from the kilns is leached at atmospheric pressure in aerated ammoniacal ammonium carbonate for extraction of its metal content. This involves six stages of leaching, including a grinding operation and five stages of washing. Solid-liquid separation is accomplished magnetically by permanent magnet machines. Dissolved nickel, copper, and cobalt are recovered as basic carbonate by steam distillation of pregnant solution in a stripping column followed by series kettles. The leached and washed magnetite is pumped to the Pellet building for agglomeration, Fig. 3.

One-half to two-thirds of the ammonia soluble nickel in the kiln product is present as a nickel-iron alloy, and the balance as nickel-iron sulfide. Although both forms of nickel are soluble in aerated ammonia-ammonium carbonate solutions, there is a marked difference in dissolution characteristics between metal and sulfide. Dissolution of the ferronickel depends upon the composition of the alloy as well as the nature of the solution. The more electronegative iron dissolves preferentially as ferrous iron, complexed by ammonium carbonate. This iron is subsequently oxidized in solution and precipitated. Solution of nickel from the alloy accompanies that of iron. It is important that oxidation of iron to the ferric state take place in solution and not on the surface of the alloy. For this reason during alloy dissolution it is essential to control redox potential at about minus 500 mv on the saturated calomel-platinum cell. At this value iron is oxidized from the elemental to the ferrous state, whereas at a redox potential of about minus 200 mv the alloy becomes passive and solution ceases. Ferrous iron dissolution is also enhanced by increasing the carbon dioxide concentration of the leach solution which should be maintained at a minimum of 3.5 pct.

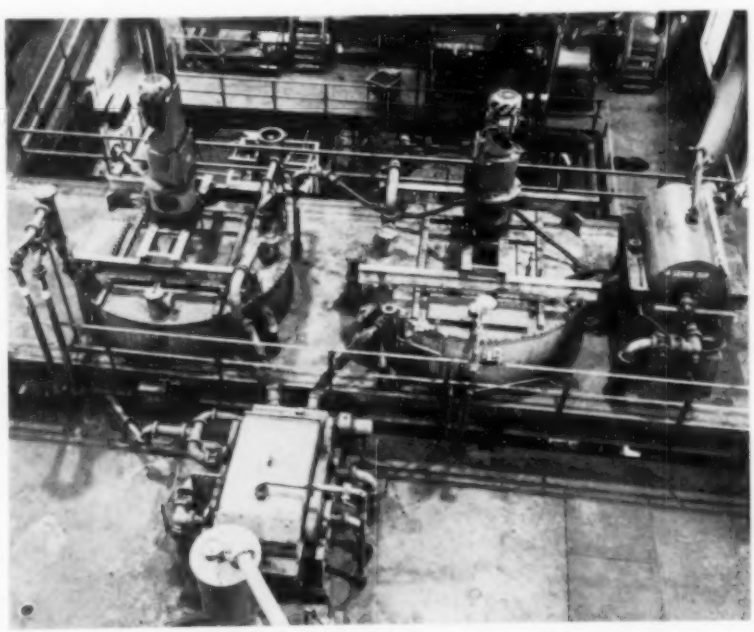


Fig. 3—Leaching tanks and permanent magnet drum thickeners for leaching the kiln product in ammoniacal solutions for extraction of nickel, copper, and cobalt.

It is well known that ferric hydroxide precipitated from nickel-containing solutions will contain nickel. The amount of ferrous iron in solution is kept within permissible limits by limiting the amount of metallic iron in the kiln product and by redox control of aeration. Dissolved copper advancing through the tanks in which ferronickel is going into solution is precipitated as sulfide by the action of these metallics. Such copper redissolves slowly and requires a higher redox potential in the last tanks of the first leaching stage than would otherwise be necessary.

Following alloy solution, aeration of the pulp is carried out at about minus 150 mv and 130°F, under which conditions nickel-iron sulfides are oxidized and dissolved. A major factor affecting the rate of this reaction is oxygen supply to the solution, an oxygen efficiency of 50 pct being obtained from air at atmospheric pressure. Leaching rate during this period is virtually linear with time and remains so until nickel in solids is decreased to about 0.2 pct. At this point, although the redox potential is increased to about −100 mv, leaching rate decreases so the magnetite is passed through a ball mill and ground to 90 pct −325 mesh. Leaching then continues until nickel in solids is reduced to 0.15 pct or less. Reagent strength throughout the circuit is maintained at approximately 6 pct NH_3 and 4 pct CO_2, addition of 17 pct NH_3, 11 pct CO_2 solution to the first tank in each stage making up vent gas losses.

Steps in leaching

Magnetite pulp is delivered to the Leaching building by pipe line feeding a 25 ft diam, 8 ft high washing thickener. Thickener overflow is discarded and underflow discharges to a sump pump where it is diluted to 30 pct solids with water. This pulp is pumped to two 3 x 3 ft drum magnetic separators in series, with a water repulp between separators. This decreases the silica content of the magnetite from 2.5 pct or more to 2.0 pct or less, and the nonmagnetic fraction analyzing about 50 pct SiO_2 is discarded. The magnetic fraction is fed at 67 pct solids to a 100-ton capacity agitated storage tank or to either of two 200-ton capacity non-agitated, hemispherical bottom, dead storage tanks. Pulp from agitated storage is pumped up to a constant head tank with an adjustable rubber orifice bottom outlet, excess pulp returning to live storage by gravity. A controlled tonnage of pulp flows through the orifice and is gravity fed to a 14 x 16 ft internal drum filter. The filter cake, at 15 pct moisture content, discharges into agitated ammoniacal ammonium carbonate solution contained in the first leaching tank.

Leaching is carried out in a total of 14 tanks, 12x12 ft but with variations in agitator design and speed. The tanks are separated into five countercurrent leaching stages with 3x3 ft Alnico permanent magnet drum separators used for solid-liquid separation between stages. Solid-liquid flow within leaching stages is concurrent to permit establishment of the necessary redox conditions. A 9x10 ft ball mill between the second and third leaching stages constitutes in effect an additional leaching stage. Pulp flow in both leaching and washing circuits is by gravity, except from the ball mill to its cyclone classifier; the solutions from the separators are pumped countercurrent to solids flow. The leaching tanks all have provision for controlled aeration and operate at a pulp density of 40 pct solids. Pregnant solution from the first stage is pumped to the Recovery building for metal and reagent recovery. About 85 pct of the extractable nickel is dissolved by the end of the second stage, and only traces of nickel are present in the fifth stage solution.

Pulp from the leaching section passes to a countercurrent washing section consisting of five 3x3 ft Alnico permanent magnet, drum separators in series. The washing so effected has an over-all efficiency of 98 pct and the magnetite from the last wash separator is repulped with water and pumped directly to the Pellet building for agglomeration. It is interesting to note that a single magnetic separator in its 6 x 6 x 5 ft housing has a 1500 tpd solids thickening capacity without loss of head, and both its operation and maintenance are simple. An additional benefit derived from the many stages of magnetic separation is a further reduction in magnetite silica content to 1.5 pct or less. Solution from the first washing stage is pumped to the Recovery building and used for the scrubbing of ammonia-laden gases.

Non-ferrous recovery

The Recovery building houses equipment required to treat pregnant solution for recovery of its nickel, copper, cobalt, ammonia, and carbon dioxide content. Pregnant solution containing approximately 1 pct solids is pumped to the purification circuit where it is received and aerated in a 12x12 ft tank. After aeration the solution is pumped through a filter press for removal of gangue and precipitated iron hydroxides. Press cake is discarded after displacement of residual pregnant solution with water. Filtrate is stored in a 90,000 gal surge tank and pumped at constant volume to the Blaw-Knox designed recovery system for metal precipitation and ammonia and carbon dioxide absorption.

The clear, substantially iron-free, pregnant solution is first passed through a six tray turbo-grid distillation column for stripping to approximately 2 pct NH_3 without significant precipitation of basic carbonate. The partially stripped solution is then fed to five kettles in series where the balance of its ammonia content is stripped, and its total metal content precipitated. Liquid is transferred from kettle to kettle by pumps, and the volume of steam used is large enough to provide adequate agitation in the kettles without mechanical assistance. Steam at 30 psi is employed, flowing countercurrent to the solution, and is consumed at a rate of about 33 pct by wt of pregnant solution. Soda ash is added to the kettles to free ammonia tied to sulfur and thereby insure an over-all metal and ammonia recovery of 99 pct or better. Basic nickel-carbonate slurry from the last kettle is passed through a heat exchanger to minimize steam flashing and then discharged to a 25-ft diam, 10-ft high thickener. Overflow is filtered and discarded, and underflow is pumped to an 8-ft diam, 6-ft long external drum filter. The cake is discharged into two steam-heated, spiral dryers, and its moisture content thereby lowered from about 75 pct to 40 pct. At this point the basic nickel-carbonate becomes powdery and is stored in dust-tight bins for further processing.

Vapors, containing ammonia and steam, leave the top of the stripping column through a heat exchanger to heat the incoming pregnant solution and

are partially condensed. The condensed water-ammonia solution is pumped to the stripping column as a reflux stream, and the uncondensed vapors flow to an ammonia recovery system. This system consists of three falling-film shell-and-tube absorbers and a packed column absorber. Indicated ammonia consumption amounts to 7 lb per long ton of iron ore pellets.

Agglomeration of magnetite

Leached magnetite is received in the Pellet building and agglomerated into hard, 1-in. balls by baking on a travelling grate. This involves dewatering of the magnetite, formation of wet *green* pellets on balling discs and drying, preheating, firing, and cooling of the pellets on a modified sintering machine. Subjection of the magnetite to high-temperature oxidizing gases for agglomerating purposes converts it to hematite and completes sulfur elimination. The sintering machine product is screened for removal of fines and shipped to market.

Choice of agglomeration practice for Inco magnetite fines was given protracted study, including tests on both laboratory and pilot plant scales. This magnetite presents a special problem due to its unusually reactive nature, having been formed at relatively low temperature and possessing a porous, coky structure stemming from sulfur elimination. A number of other factors were considered important including the desire to maintain the ore's excellent chemical analysis by avoiding use of additives such as solid fuels or bentonite and to produce pellets with excellent physical properties. The conclusion reached was that the Lurgi pelletizing process most nearly met requirements, and Lurgi designed equipment for pellet production was purchased from Dravo Corp.

Leached magnetite is received at 30 pct solids and thickened magnetically to 67 pct solids. The resulting slurry is fed to a 100-ton capacity agitated tank for live storage or to either of two 875-ton capacity tanks for dead storage. The magnetite concentrate is pumped to two 14x16 ft internal drum filters, each having a capacity of 45 tons per hr. The 15 pct moisture filter cake is stored in a 60-ton capacity rotating bin-table feeder. This storage feeder provides an accurate method of distributing magnetite to the three Lurgi balling discs. These discs are 16 ft in diameter and 15 in. deep, incline at an angle of 45° and turn at 4 rpm. Each disc has a capacity of at least 20 long tons per hr of 1-in. pellets. The product from the discs is evenly sized, and the 16.5 pct moisture green pellets have a crushing strength of about 4 lb without additives. The balling disc product is transported to the sinter machine on a system of belt conveyors. The machine is charged evenly by means of an 8 ft wide x 11 ft long re-roll conveyor belt which travels upward on an incline so that only well made pellets can roll down it. Fines and broken pellets are thus removed from the charge just prior to feeding the sinter machine, since the former cling to the belt and are returned to the agitated storage tank.

Lurgi sintering machine

The sinter machine, 8 ft 2½ in. wide with 158 ft over the windboxes, is rated at 1200 long tons per day of 1-in. pellets. It is equipped with 124 pallets 40 in. in length, made of ductile iron or cast steel with 25 pct Cr, 12 pct Ni cast steel grate bars. Total area over the 24 windboxes is about 1300 sq ft, of which about 1000 sq ft is used for down-draft drying, preheating, and firing, and the balance for updraft cooling. Pallets and grate bars are protected from excessive heat by the use of a hearth layer of +5/16 in. fired pellet chips and side plates are protected by a side-wall layer of −5/16 in. +⅛ in. chips. Charge depth is 20 in. and normally consists of 4 in. of grate layer and 16 in. of green pellets. Present fuel consumption approaches 2,000,000 Btu per ton of product, but this will be sharply reduced when the machine is operating at rated capacity rather than the present 60 pct of capacity.

The magnetite quickly oxidizes at 800°F so that heating of the pellets must be closely controlled to prevent *flash* oxidation. Firing of the pellets is, therefore, carried out in four zones: a) Drying Zone: 47 ft long, covering the first 7 windboxes. Hood temperature is held at 700°F by recuperated air and windbox temperature is 150°F; b) Preheat Zone: 20 ft long covering windboxes 8 to 10 inclusive. Hood temperature is held at 1100°F by oil burners and windbox temperature increases to 225°F; c) 1st Firing Zone: 26 ft long, covering windboxes 11 to 14 inclusive. Hood temperature is gradually increased to 2000°F by oil burners, and windbox temperature increases to 500°F; d) 2nd Firing Zone: 34 ft long covering windboxes 15 to 19 inclusive. Hood temperature is held at 2450°F by oil burners, and windbox temperature increases to 1100°F. The pallets then pass into the cooling zone where air is blown up through the charge at a controlled rate.

Windboxes 1 to 12 are exhausted to atmosphere by a remote control variable speed fan, and windboxes 13 to 19 inclusive are exhausted to the recuperation gas flue by another remote control variable speed fan. The cooling air is heated to 950°F and is exhausted to the recuperation gas flue by a remote control variable speed fan. The recuperated hot gas is drawn from the circulation gas flue into the drying zone as required and also into the preheating and firing zones, where it is heated to final temperature by oil burners.

Product: High Grade 1-in. pellets

The fired and cooled pellets are subjected to a double screening operation, the undersizes consist of coarse chips for use as hearth and side-wall layers and −⅛ in. fines for return to the agitated storage tank. The oversize consists of approximately 1-in. pellets which yield about 10 pct of −28 mesh material when subjected to the ASTM Tumble Test and analyze: 68 pct Fe, 0.003 pct P, 1.5 pct SiO_2, 0.05 pct Mn, 0.65 pct Al_2O_3, 0.25 pct CaO, 0.30 pct MgO, 0.01 pct S, 0.05 pct Cr_2O_3, 0.15 pct TiO_2, 0.15 pct Ni, 0.01 pct Cu and 0.0 pct L.O.I. This premium product has been used very successfully as open hearth charge ore by the steel industry in both Canada and the United States and is believed to be the highest quality iron ore produced in quantity in North America.

References

[1] Development of the Inco Iron Ore Recovery Process by The Staff of The International Nickel Company of Canada, Ltd., *The Canadian Mining and Metallurgical Bulletin*, May, 1956.

[2] Patents pending.

[3] P. E. Queneau, W. K. Sproule, and A. Illis; U.S. Patent 2,556,215, June 12, 1951.

[4] K. J. E. Meyer and Hans Rausch: "Lurgi Pelletizing Process," JOURNAL OF METALS, February 1958.

[5] J. B. McKay, E. J. Roberts, and F. L. Bosqui: U.S. Patent 2,677,608, May 4, 1954.

NEW TECHNIQUES FOR COPPER REFINING

by E. F. Kurzinski

The use of oxygen in steelmaking, now well established, points toward similar advances in copper refining with this now-inexpensive industrial gas.

IN scanning the field of metal refining, the copper industry most nearly approaches the steel industry in its operations. Converters, blast furnaces, and large, fuel-fired, batch-type furnaces are used in both industries. Even with these similarities, however, there are a number of differences. The copper industry makes use of copper-bearing ores containing 2 pct Cu and less. The steel industry, on the other hand, is geared to use ores with an iron content of about 50 pct in the US. The copper industry has developed novel techniques to produce profitable quantities of gold, silver, selenium, and tellurium from ores containing seemingly insignificant quantities of these elements. On the other hand, in the steel industry, open hearth slags are discarded containing up to 21 pct manganese oxide. Thus, in many respects, the copper industry can be considered to be metallurgically more advanced than the steel industry. Both industries are always looking for methods to increase production with minimum capital investment, to improve quality, or to reduce operating costs. Industrial gases feature prominently in many of these plans.

Cost of oxygen[1]

The cost of oxygen has decreased substantially since 1907, when the first air separation plant was started in the US. Initial delivery was in cylinders, and oxygen cost about $2.50 per 100 cu ft to *large* consumers. Marked reductions in oxygen cost were made for the large consumer when techniques were developed for transportation, handling, and distribution of oxygen in liquid form. However, even with these improvements, oxygen could not be considered for widespread application because the costs were still excessive. It was only with the development of oxygen generating plants, which could be located on the site of the consumer, that the cost of oxygen was reduced sufficiently to permit its consideration for use in many industrial applications. Typical costs for oxygen from these on-site generators vary from $5 to $25 per ton, depending on the type and size of the installation.

E. F. KURZINSKI is Mgr. of Sales Development Engineering at Air Products Inc., Allentown, Pa.

Oxygen in steel converters

Bessemer converters in the US have been using oxygen-enriched air to aid in the melting of additional scrap. As reported by W. G. McDonough,[2] use of 4000 to 6000 cu ft O_2 per blow permitted the steel scrap charge to be increased by about 4000 lb and the blowing time to be decreased by 1 min in 28-ton converters. In Europe, considerable progress has been made applying oxygen to steel production.[3]

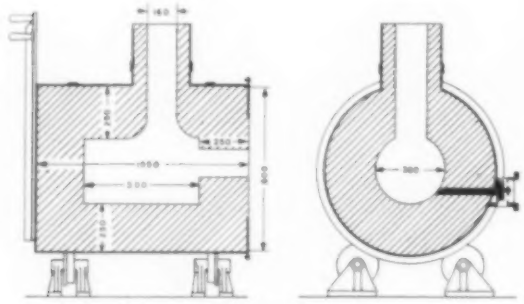
Of greater importance in the US is the LD process.[4] Theoretically, depending upon hot metal chemistry, up to 45 pct cold scrap can be melted using this oxygen technique. In actual practice, about 25 pct cold steel scrap is charged into the LD converter. Two steel plants in the US are using the LD process at the present time, while three more are installing facilities for oxygen top-blowing. The LD process is characterized by high steel production rates and high oxygen utilization efficiencies.

. . . in copper converters

One possible application for oxygen in the copper industry is in converting matte. Presently, air is used for this purpose. Oxidation of matte in the converter results in reduction of copper to the metallic state, oxidation and separation of iron to the slag, and liberation of sulfur dioxide gas.

Information on the uses of oxygen for copper converting is very limited in literature. In 1904, Borchers[5] conducted experiments on converting copper matte using air enriched to 25 to 28 pct O_2. He reported that the advantages of using oxygen were immediately evident by the high temperatures generated during the blow and the intensity of the reactions. In 1934, S. Tonakanov[6] concluded that blowing with oxygen-enriched air gave improved

results in converting copper matte. Tonakanov used a special laboratory converter similar to that shown in Fig. 1. The oxygen concentrations in the air used during the tests varied from 21 to 38 pct. Results of Tonakanov's experiments showed increases in the converting rate, the process temperature, tuyere life, and sulfur dioxide in the exhaust gases. He also reported that oxygen enrichment resulted in a satisfactory copper product with no increase in the impurity levels, a normal and highly fluid slag, and no adverse effects on lining life.



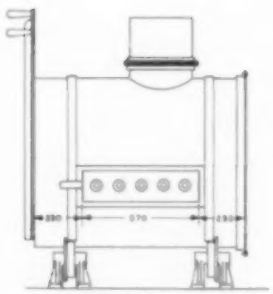


Fig. 1—Tonakanov laboratory converter. For blowing copper matte. Dimensions in mm.

More recently, larger scale oxygen enrichment tests were made in a copper smelter producing blister from the black copper products of a blast furnace. The black copper contained 84 to 86 pct Cu, about 10 pct Zn, with the remaining impurities being iron, tin, lead, nickel and sulfur. The converter charge consisted of 10,000 lb of molten black copper which, following conversion, gave about 8000 lb of blister. The converter was equipped with an oil burner to maintain converter temperatures at about 2000°F when using air as the oxidizing medium at a flow rate of 600 cfm. The blowing cycle ranged from 60 to 90 min, depending upon the impurities in the black copper. Experimental runs were made in which the oxygen content of the converter blast was increased up to 27 pct. The optimum practice developed for this particular converter was to use air alone during the early stages of converting, when the impurity levels were high. Blowing air was then enriched with oxygen to speed up the reactions in the final stages of converting.

Table I shows the chemical composition of the black and blister coppers for two typical oxygen tests. The conclusions of the test program were that blow time could be decreased by at least 30 pct with an oxygen consumption averaging 100 cu ft per ton of blister copper produced. In addition, the burner was eliminated, thereby effecting a saving in oil

Table I. Results of Converting Black Copper with Oxygen-Enriched Blast

	Cu, Pct	Fe, Pct	S, Pct	Sn, Pct	Pb, Pct	Ni, Pct
(A) Before Blowing	84.26	7.42	0.568	1.02	1.98	0.92
After Blowing	96.28	0.04	0.021	0.30	0.44	0.32
(B) Before Blowing	83.46	5.04	0.615	2.16	4.18	1.92
After Blowing	96.26	T	0.042	0.05	0.76	0.30

A—51 min total blowing time—35 min with no oxygen followed by 16 min at 6 pct O_2 enrichment.
B—70 min total blowing time—35 min with no oxygen followed by 35 min at 3 pct O_2 enrichment.

consumption. No apparent damage was evident to the tuyeres or refractory lining in these limited production tests.

Can copper refiners use oxygen blowing in converting matte? Oxygen-steam mixtures can be introduced with minimum modification to the present converter design. Cold copper could be charged at intervals to control temperatures. If excessive hydrogen pick-up is experienced by the copper, it could be removed by a final nitrogen purge of short duration.[7]

Probably of greater benefit, would be use of the oxygen top-blowing technique as shown in Fig. 2. Oxidation of matte by oxygen is highly exothermic, and about 5,000,000 Btu's will be evolved per ton of copper treated. Metal temperatures could be controlled by the addition of cold scrap.

Oxygen top blowing technique would increase production rates over present converter practices because greater overall thermal efficiency would be realized, since the sensible heat lost in the nitrogen when air blowing would be eliminated. The size of the flue system could be reduced. Then, by maintaining a tight fitting hood over the converter mouth to reduce dilution of converter gases by atmospheric air, it should be possible to maintain higher sulfur dioxide concentrations in the exhaust gases for more efficient production of liquid sulfur dioxide or sulfuric acid. Top blowing should increase refractory life since the *hot spot*, or reaction zone, will be located immediately opposite the oxygen jet which is positioned in the center of the converter vessel. On the other hand, the hot spot with conventional bottom blowing converters is directly in front of the tuyeres and, therefore, immediately adjacent to the

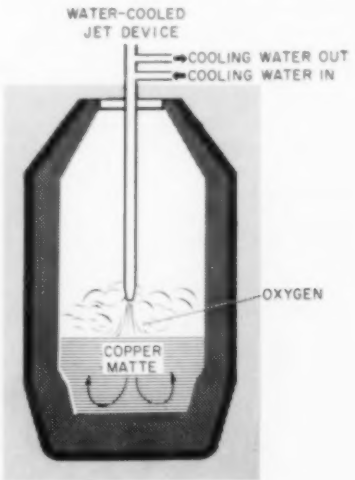


Fig. 2—Converting copper matte using an oxygen top-blowing technique.

refractory lining in the vessel. It is quite possible that present Pierce-Smith or Great Falls converter designs can be modified to use the oxygen top blowing technique.

Combustion enrichment in open hearth furnaces

The steel industry began investigating gaseous oxygen additions to open hearth burners shortly after World War II. Considerable enthusiasm marked the initial tests, since steel production rates were increased considerably. As experimental production trials progressed, this initial enthusiasm was tempered by excessive damage to furnace refractories. After a period of inactivity, oxygen additions to open hearth end burners again came under attention about 1953. Many designs of oxygen-consuming open hearth burners were developed to utilize oxygen.

Advantages of using oxygen in open hearth burners are more efficient combustion of additional fuel and increased flame temperature. The usual practice is to add oxygen and additional fuel, so that the waste gas volume is essentially the same as with non-oxygen practice. Oxygen effectively shortens the length of the flame. As a result, additional fuel can be burned without tailing the flame into the checkers with the possibility of severe refractory damage. The effect of oxygen on flame temperature is pronounced. The theoretical flame temperature for fuel oil burning in air is 3630°F; if fuel oil is burned in air containing 40 pct O_2, flame temperature is increased to 4475°F.

. . . in copper furnaces

Can oxygen be used for combustion intensification in both anode and cathode copper refining furnaces? In the steel industry, incoming air is heated to temperatures as high as 2300°F; copper furnaces do not have the benefit of combustion air preheated to such high temperatures. As a result, oxygen enrichment of the burner flame for copper furnaces should provide considerably greater thermal benefits since a lesser quantity of inert nitrogen would pass through the furnace. In addition, the thermal conductivity of copper is about eight times greater than that of steel. Therefore, heat will be transferred at a greater rate, and maximum firing rates can be used with less danger to furnace refractories when compared to steel practice.

In most copper refineries, it is desired to operate the furnaces on a 24-hr cycle for a five day week. By using oxygen, it should be possible to increase the oil firing rate and control heat time to the desired 24-hr period. The cost of oxygen would be balanced by elimination of overtime costs presently incurred by having furnace crews work on Saturdays. In periods of lower demand for copper, oxygen could be used to increase the melting rate and thereby melt more charge in the same period of time so that desired production could be obtained with fewer furnaces.

Jet blowing in open hearth furnaces

Use of vertically-positioned, water-cooled roof jets blowing oxygen onto the steel in open hearth furnaces is being widely investigated in the US at the present time. With roof jets, steel production increases range from 15 to 40 pct. Oxygen is introduced through the jets shortly before or immediately after the addition of hot metal. Oxygen is generally added through two roof jets positioned opposite No. 2 and No. 4 doors in the conventional five-door open hearth furnace, although some mills are experimenting with one water-cooled jet positioned opposite the middle door. Purpose of the oxygen is to rapidly oxidize the carbon, silicon and manganese.

Oxygen flow rates for open hearth roof jet practice vary between 10,000 and 50,000 cu ft per hr. Overall oxygen consumption varies between 350 and 700 cu ft per ton of steel. To date, open hearth roof jets have not been applied on a wider scale because open hearth roof life is reduced by this practice. It is highly possible, however, that continued investigation will evolve a practice which will maintain substantial increases in steel production without causing any significant decrease in refractory life.

. . . in copper furnaces

Following melt-down in the copper furnace, air is added through multiple pipes to oxidize the impurities. One procedure for a 300-ton cathode furnace is to add compressed air through seven 1-in. pipes, each blowing at a rate of about 18,000 cu ft per hr. Another practice is to introduce the air through five $\frac{3}{4}$-in. pipes. This blowing or *flapping period* takes approximately 3 hr. Would it not be easier and more efficient to introduce oxygen through a vertical, mechanically operated, water-cooled roof jet positioned centrally in the anode or cathode furnace to speed up production rates? By the roof jet technique, the oxidation period would be shortened, manual effort on the part of labor would be reduced, and traffic in front of the furnace would be improved, since interference from hose and piping would be eliminated.

Additions of alloys and chemical agents in the steel industry by fluidjection

Many materials are added during metal processing to effect chemical reactions or alloying; usually these materials are added in bulk. The additions can be made in the furnace, in the ladle, or in the mold. In the past ten years, a new technique called *fluidjection* has been developed to add more efficiently many materials to molten metals.

In fluidjection, the material to be added to the molten bath is introduced in powder form. The powder is placed in a dispenser, the function of which is to meter the powder material and to mix it with the conveying gas. The powder-conveying gas mixture, now having the properties of a fluid, passes through a refractory tube positioned below the metal surface. The process is shown schematically in Fig. 3. The conveying gas can be either inert or chemically active to best suit the requirements of the particular process. Thus, in dephosphorization of steel, which is enhanced by oxidizing conditions, oxygen is the preferred conveying gas. On the other hand, in processes best carried out under reducing conditions, the conveying gas can be methane or propane. Where explosive hazards exist, it is generally preferred to substitute an inert gas, such as nitrogen or argon, for methane or propane.

When compared to bulk addition techniques, additions made by fluidjection result in better uni-

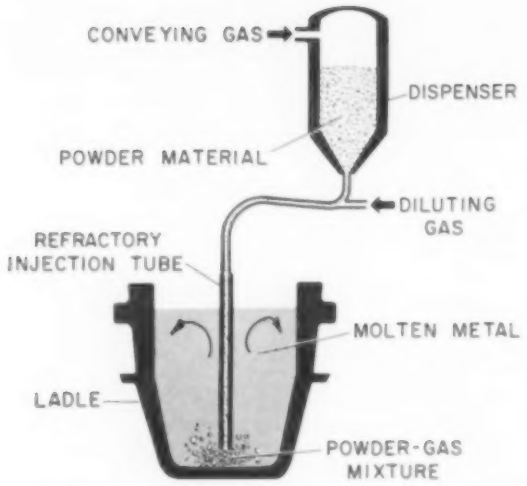


Fig. 3—Fluidjection process for conveying and injecting powdered materials into molten metal baths.

formity, greater recovery, and less segregation in the treated product. If the conveying gas is inert, it provides the additional benefit of flushing dissolved gases from the molten metal which results in a sounder cast product. Fluidjection also permits the controlled addition of highly explosive materials, such as magnesium powder, which cannot be added safely by the bulk technique.

Fluidjection is presently used in the steel industry to remove sulfur from hot metal by means of nitrogen-conveyed calcium carbide. Introducing bulk calcium carbide into the bottom of a ladle and then filling the ladle with molten iron results in a carbide consumption of 12 lb per 0.010 pct S reduction per ton iron treated. If powdered calcium carbide is continuously added in bulk onto the surface of the iron in a runner during a blast furnace cast, carbide consumption will be approximately 8 lb per 0.010 pct S reduction per ton iron treated. With fluidjection, carbide consumption will be 1.5 to 4 lb. Cost of the nitrogen conveying gas is only a small fraction of the total of the calcium carbide. The steel industry is also investigating injection of calcium cyanamid for desulfurization of hot metal because of its lower cost and safety considerations.

Leaded steels are presently made by impinging powdered lead conveyed in an air stream onto the teeming stream. Also successful tests have been made adding powdered ferromanganese into the steel stream during tapping of an open hearth. Flow rates of ferromanganese as high as 1000 lb per min have been made, and examination of the cast product showed standard segregation and improved manganese recovery.

Fluidjection in the copper industry

Can fluidjection be applied to advantage in copper refining? Can phosphorous alloy be added to produce dephosphorized copper? Powdered chromium conveyed in an argon stream has been added to copper with 90 pct Cr recovery. Calcium carbide or calcium cyanamid may prove desirable to simultaneously desulfurize and deoxidize copper. Limited laboratory tests in 100 lb heats of copper melted under a charcoal cover in induction furnaces have shown that calcium carbide will reduce oxygen content in molten copper from 0.830 to 0.008 pct. No work has been done with calcium cyanamid for sulfur and oxygen reduction in molten copper.

Inert gas stirring in the copper industry

Inert gases can be used to advantage as stirring agents. The alloying or reaction agent can be added on the surface of the molten copper, and by means of an inert gas introduced below the molten metal surface, better mixing can be attained. In tests in a copper refinery, phosphorus-copper alloy was added to a 550 lb ladle of copper taken from a billet furnace. One series of billets was made in the conventional manner adding phosphorous-copper shot followed by mechanical stirring. The second series was made using bulk addition and nitrogen gas stirring. Both ladles of copper were covered with charcoal. The copper was then poured into 3-in. billets. Chemical tests were made throughout the lengths of the billets. Phosphorus content varied from 0.016 to 0.025 pct for the standard practice dephosphorized copper. Billets produced in which nitrogen stirring was used showed a phosphorous variation of 0.019 to 0.020 pct.

Can nitrogen mixing be used to improve the quality of high conductivity phosphorous deoxidized copper utilizing the information gained in the nitrogen stirring tests? In producing phosphorized copper, sufficient phosphorus is added to react with all the oxygen in the copper and to provide for a residual phosphorus of 0.015 to 0.025 pct. This residual phosphorus reduces the electrical conductivity of the copper to only 85 to 88 pct and precludes its use for electrical applications.

By nitrogen stirring, improved phosphorus uniformity has been attained throughout the copper bath. Thus, it should be possible to add only the specific quantity of phosphorus to provide for the elimination of oxygen. One suggested technique for adding the phosphorus is shown in Fig. 4. Phosphorous-copper shot can be added to the copper in the ladle and stirred by nitrogen gas injected through a graphite tube fixed in the graphite cover. The nitrogen will thoroughly mix the phosphorus alloy in the copper without incurring atmospheric oxidation or metal splashing.

Another possibility would be to introduce phosphorus vapors below the molten metal surface by means of inert gas streams. Heat from the bath can be used to vaporize the phosphorus alloy.

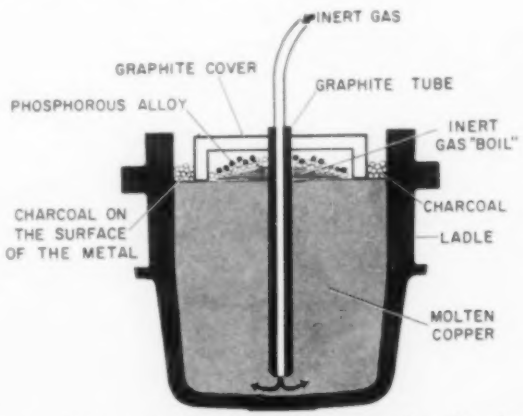


Fig. 4—Technique for adding phosphorous-copper alloy using nitrogen stirring.

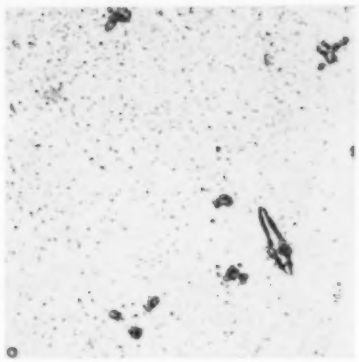


Fig. 5a—Photomicrograph showing copper after treatment with a solid stream of oil. Oxygen content 0.64 pct. 75X.

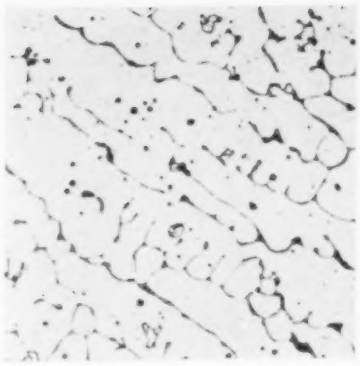


Fig. 5b—Photomicrograph showing copper after treatment with nitrogen-atomized oil. Oxygen content 0.07 pct. 100X.

Reducing the oxygen content in copper

In *flapping*, copper is oxidized to 0.6 to 0.8 pct O_2 to remove the impurities into the slag. Usual practice is to introduce *poles*, and by destructive distillation reduce the oxygen content to 0.03 to 0.05 pct to produce tough-pitch copper. Poling costs vary widely in the US; on the Eastern Seaboard poling costs about $0.30 per ton of copper treated. A problem in this area is that the supply of suitable poles is being depleted. In some areas of the Southwest, poles have to be transported for great distances and have to be kept moist during storage, increasing poling cost.

Investigations have shown that copper can be effectively deoxidized by the addition of various reducing agents such as oils, powdered coal, propane, coke, or saw dust. Fluidjection can be applied to introduce powdered reducing agents into molten copper to improve the reaction efficiency. Little test work has been done to date.

Small scale tests were made in which oil was used to deoxidize copper. In these tests 200 lb of copper was melted down and then oxidized with copper oxide. One hundred pounds was poured into another crucible and treated with a solid stream of oil injected below the surface of the copper. The remaining 100 lb was then treated by injecting a similar quantity of oil which was atomized by nitrogen prior to the injection. The results of these laboratory tests confirmed production tests in that no reduction of the oxygen content in the copper was effected when oil was added as a solid stream. The oil rose to the surface of the molten copper and burned with the evolution of copious quantities of carbon smoke. Fig. 5a is a photomicrograph of copper after treatment with a solid stream of oil. In this case 0.80 lb of oil was injected into 100 lb of copper previously oxidized to contain 0.64 pct O_2. As can be seen, no oxygen was removed from the copper after treatment with a solid oil stream. Introduction of the same quantity of oil which had been atomized with 1.3 cu ft N_2 prior to injection effected a marked reduction in the oxygen content in the copper, as shown in Fig. 5b. Chemical analysis showed that the oxygen content was reduced from an initial of 0.64 pct to 0.07 pct.

No large scale tests were made using the nitrogen-oil technique. In full scale trials, it is expected that the process efficiency would increase, since the metal depth in the anode or cathode furnace is considerably greater than the 8 in. metal depth in the crucible tests. The increase in metal depth is favorable to the reaction, since there would be proportionally greater contact between the oil and the copper when the oil is injected in the deeper bath.

With this nitrogen-atomized oil technique, it was possible to reduce the oxygen content in the copper to a level of .008 pct. Porosity was evident in the test samples cast following this treatment. The porosity was probably caused by separation of dissolved or reaction gases. The dissolved gases can be removed by flushing with an inert gas. Would it be possible to produce oxygen-free high conductivity copper at lower cost by using the nitrogen-atomized oil technique, followed by inert gas flushing?

Mold treatments

At the present time in the steel industry, the more critical grades of steel, such as steel for turbine rotors, are being cast using either an inert gas or a vacuum casting technique. Without these techniques, steel is oxidized by the oxygen in the atmosphere during the teeming operation. The oxidized steel does not fuse back into the ingot body and becomes imbedded in the ingot surface. The discontinuities resulting from these oxidized particles cause stress risers which become ingot surface breaks during working. By means of inert gas purging of molds or vacuum casting, oxidation of the steel is eliminated and a sounder ingot is cast.

Can inert gas mold purging be applied in the copper industry to overcome some of the problems experienced with defects on the billets, cakes, and bars? In this case, nitrogen could be used as the purging gas, since nitrogen does not enter into reactions with copper, and the solubility of nitrogen in copper is extremely low.

Summary

It is possible that a number of uses of industrial gases in the steel industry could find applications in refining copper. Further study and experimental tests will be required to determine if industrial gases can be used in refining copper to give greater flexibility in controlling production rates and costs.

References

[1] A. E. Steele and D. E. Cummings: Economics of Oxygen Generating Stations for Steel Mill High and Low Purity Oxygen Applications, *Iron and Steel Engineer*, June 1957.

[2] W. G. McDonough: Oxygen as a Means of Increasing Bessemer Production, General Meeting of American Iron & Steel Institute at New York, May 23-24, 1951.

[3] Gittusson: Evolution of the Thomas (Basic Bessemer) Steelmaking Process in Europe, *Metal Progress*, Jan. 1954.

[4] a. D. O. Davis: The Oxygen Steelmaking Process, *Iron and Steel Engineer*, October 1955. b. C. R. Austin: Oxygen Steel in the United States, *Iron and Steel Engineer*, May 1956.

[5] *Mettalurgie*, 1904, I, p. 182.

[6] S. Tonakanov: Blowing With Oxygenated Air, *Engineering and Mining Journal*, Dec. 1934.

[7] E. F. Kurzinski: Degassing Non-Ferrous Metals, *Foundry*, Dec. 1948 and Jan. 1949.

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SOCIAL PROGRAM

Thursday, October 23

——Welcoming Luncheon, 12 noon @ $4.25 $_____
——Cocktail Party, 6:00 to 7:30 pm, free with registration

Friday, October 24

——Dinner-Dance, 7:00 pm @ $9.00 $_____

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FIELD TRIP RESERVATION

Thursday, October 23

——Coal Trip, 8:00 am @ $2.00 $_____
Peabody Coal Co., Freeburg, Ill., mine and barge loading facilities

OR

Friday, October 24

——All-Day Mining and Milling Trip, 7 am to 5 pm @ $5.00 $_____
Indian Creek Mine and Mill of St. Joseph Lead Co. near Potosi, Mo.; Pea Ridge deep iron shaft site.

OR

——Granite City, 8 am to 12 noon @ $1.50 $_____
Trip limited to 75; Granite City Steel Mill, Granite City, Ill.

OR

——Dow Chemical, 8 am to 12 noon @ $1.50 $_____
Trip limited to 200; Dow Chemical Co. magnesium extrusion and rolling plant

OR

——Cement Trip, 8 am to 12 noon @ $1.50 $_____
Trip limited to 100; Missouri Portland Cement Co.

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LADIES' PROGRAM

——Registrations @ $1.00 $_____

Thursday, October 23

——Coffee Hour, 9:30 am to 11:30 am, free with registration

Friday, October 24

——Luncheon, Fashion Show, 12:30 pm @ $5.50 $_____

Saturday, October 25

——Bus Tour of St. Louis, 9:30 am @ $2.25 $_____

Tickets to events for which you have registered will be held in your name at the meeting registration desk.

Mid-America Minerals Conference

Thursday, October 23, AM

Minerals Beneficiation

R. H. Lowe, *Chairman*, and D. C. Spees, *Co-Chairman*

9:00—Recent Advances in Milling Practice: *H. A. Hoffman*, St. Joseph Lead Co.

9:30—Leaching Copper from Zinc Concentrates: *Norman Hedley* and *Howard Tabachnick*, American Cyanamid Co.

10:00—Application of Ore Dressing Microscopy: *C. G. Amstutz*, Missouri School of Mines.

10:30—Two-Stage Cyclones at White Pine: *Virgil Lessels*, White Pine Copper Co.

11:00—Bulk Solids Flow: *Andrew Jenicke*, University of Utah.

Geology and Geophysics

LeRoy Scharon, *Chairman*

9:00—Iron in Missouri, *John S. Brown*, St. Joseph Lead Co.

9:30—Kentucky Fluorspar District—Its Geology and Exploration: *John S. Tibbs*, Calvert City Chemical Co.

10:00—Geophysical Exploration Techniques: *Willard E. Davis*, U. S. Geological Survey.

10:30—Application of Geology to the Discovery of Zinc-Lead Ore in the Wisconsin-Illinois-Iowa District: *J. C. Bradbury*, Illinois Geological Survey.

11:00—Sedimentation Breccias in Southeastern Missouri Lead Mines: *Frank Snyder*, St. Joseph Lead Co.

Thursday, October 23, PM

Mining

Fred D. Wright, *Chairman*

1:30—Some Performance Parameters of Ammonium Nitrate-Fuel Oil Explosives: *George B. Clark*, Missouri School of Mines.

2:00—New Developments and Use of Ammonium Nitrate Explosives: *Dort F. Tikker*, Monsanto Chemical Co.

2:30—A Case History in Pillar Recovery: *John Reed*, St. Joseph Lead Co.

3:00—The Piokee Project—An Experiment in Mining Efficiency: *Joseph S. Elizondo*, The Eagle-Picher Co.

3:30—Blast-Hole Mining at Geco: *G. M. T. Marshall*, Geco Mines Ltd.

Coal

Jack A. Simon, *Chairman*, and Gene H. Utterbach, *Co-Chairman*

Coal Operations

1:30—Shaft Sinking and Lining in the Southern Illinois Coal Field: *J. W. MacDonald*, Old Ben Coal Corp.

2:00—Preparation of Fine Coal: *Emery Milligan*, Freeman Coal Corp.

2:30—Ventilating Problems in Continuous Mining Operations: *D. S. Kingery*, U. S. Bureau of Mines.

Coal Economics

3:00—Fuels Used in Manufacturing: *W. H. Voskuil*, Illinois State Geological Survey

3:30—Inventories—Aid and Deterrent to Coal Industry Stability: *H. E. Risser*, Illinois Geological Survey.

Friday, October 24, PM

Extractive Metallurgy

H. R. Bianco, *Chairman*

1:30—Developments in Cooperative Zinc Research: *D. W. Pettigrew*, American Zinc Inst.

2:00—Nickel and Cobalt Extraction at Fredericktown, Missouri: *R. M. McCormick*, National Lead Co.

2:30—Mechanical Charging of Horizontal Zinc Retorts: *B. F. Buff*, National Zinc Co.

3:00—Continuous Strip Galvanizing at Granite City: *Eloy M. Cueto*, Granite City Steel Co.

3:30—Continuous Casting of Magnesium: *John L. Scherer*, Dow Chemical Co.

Industrial Minerals

Thomas R. Beveridge, *Chairman*, and William Hayes, *Co-Chairman*

1:30—Fluorine Reserves and Potential Recovery from Domestic Phosphate Rock: *E. F. Dressner* and *G. F. Palm*, International Minerals and Chemical Corp.

2:00—Barite in Washington County, Missouri—History and Development: *E. L. H. Sackett*, National Lead Co.

2:30—Undeveloped Industrial Rocks and Minerals of Missouri: *T. R. Beveridge*, Missouri Geological Survey.

3:00—Utilization of Red Mud from Alumina Refining Plants: *N. L. Shepherd*, Aluminum Co. of America.

3:30—Shale Testing in Illinois for Lightweight Aggregates: *Arthur White*, Illinois Geological Survey.

4:00—A Study of Missouri Bloating Clays and a Suggestive Mechanism for the Bloating Process: *T. J. Plantje*, Missouri School of Mines.

Saturday, October 25, AM

Iron Symposium

Robert Geehan, *Chairman*

9:00—**Supply**
Trends Related to Sources of Iron Ore: *H. T. Reno*, Bureau of Mines.

9:30—**Geology and Prospecting**
Iron Ores of Missouri, with Special Reference to Recent Exploration: *William C. Hayes*, Missouri State Geologist.

10:00—**Drilling**
Drilling and Sampling Methods in East Texas: *A. B. Drescher*, Lone Star Steel Co.

10:30—**Mining**
Underground Mining of Iron Ore at the Ozark Ore Co. at Iron Mountain, Mo.: *R. P. Matson*, Ozark Ore Co.

11:00—**Milling**
Experiments in the Concentration of Iron Ore from the Pea Ridge Deposit, East Central Missouri: *M. M. Fine*, U. S. Bureau of Mines.

11:30—**Utilization**
Paper to be announced later.

Field Trips

Thursday, October 23, AM

Coal

Peabody Coal Co., Freeburg, Ill., mine and barge loading facilities; trip to start at 8 am.

or

Friday, October 24

All-Day Trip

7 am to 5 pm

Mining and Milling
Indian Creek Mine and Mill of St. Joseph Lead Co. near Potosi, Mo.; Pea Ridge deep iron shaft site.

or

Morning Trips

8 am to 12 noon

Extractive Metallurgy: Granite City Steel Mill, Granite City, Ill.

or

Dow Chemical Co., magnesium extrusion and rolling plant, Madison, Ill.

or

Cement: Missouri Portland Cement Co., mining and processing plant.

General Social Events

Thursday, October 23

Welcoming Luncheon

12:00 noon

Speaker: *Felix Wormser*, vice president, St. Joseph Lead Co.

Subject: *Economic Conditions in the Metal Industry*

Cocktail Party

6:00 to 7:30 pm

Sponsored by companies within the AIME St. Louis Section area.

Friday, October 24

Dinner-Dance

7:00 pm

Khorassan Room — Chase Hotel

Speaker: *Augustus B. Kinzel*, AIME President, Union Carbide Corp.

Subject: *Metals, Missiles, and Men*

Ladies Program

Thursday, October 23

Coffee Hour

9:30 to 11:30 am

Friday, October 24

Luncheon and Fashion Show

12:30 pm

Tiara Room — Park-Plaza Hotel

Fashion Show by Montalbo's.

Saturday, October 25

Bus Tour

9:30 am

Bus tour of city of St. Louis

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AIME NEWS

AIME

BOARD OF DIRECTORS

Recent actions taken by the Institute Board of Directors.

► The following change in the AIME Bylaws has been proposed: **Article III,** *Section 1*—Change "Admissions Fees" to "Entrance Fees". Change to be made whenever applicable in Bylaws and Rules.

► Augustus B. Kinzel represented the AIME Board of Directors at the Golden Jubilee of AIChE during the week of June 22 to 27, 1958, and presented a Scroll of Greetings to the chemical engineering group from the Institute.

► Augustus B. Kinzel has been appointed as AIME representative to a four-year term on the John Fritz Medal Board of Award. F. B. Foley has been reappointed as alternate.

► The following personnel have been appointed for the Committee on Honorary Membership: H. DeWitt Smith, chairman; C. E. Reistle, Jr., 1959, Grover J. Holt, 1959, L. F. Reinartz, 1959, M. L. Haider, 1960, D. H. McLaughlin, 1961, John M. Lovejoy, 1962, ex officio as Past-Presidents of AIME; and Augustus B. Kinzel, ex officio as AIME President.

► H. N. Appleton and John F. Lynch have been appointed representatives to the Engineering Societies Personnel Service.

► H. H. Chiswik was appointed AIME representative to the 1959 EJC Nuclear Congress and will serve on the Conference Committee.

► J. C. Fulton, Chairman of the ISD Publications Committee, has been appointed to the Rossiter W. Raymond Award Committee.

► The AIME Board of Directors will meet in Salt Lake City on Friday afternoon, September 19, 1958, at 2 pm during the AIME Rocky Mountain Minerals Conference.

► J. C. Kinnear, Jr., was appointed Contact Director on the AIME Board at the Executive Committee Meeting of the Council of Education.

► In accordance with AIME Bylaws, *Article V*, **Section 4(a)**, President Augustus B. Kinzel has appointed J. S. Vanick as Contact Director to coordinate the rules of the three Society Admissions Committees.

► J. Roy Gordon, executive vice president of International Nickel Co. Inc. was appointed alternate to H. DeWitt Smith on the Hoover Medal Board of Award for a term to expire in 1960.

► John D. Sullivan has been nominated as AIME representative on the Advisory Board of the Office of Critical Tables of the Academy Research Council, National Academy of Sciences.

► Frank Sisco has been reappointed as AIME representative on the Engineering Societies Library Board for a four-year term.

► R. A. Beals has been appointed AIME representative to the American Standards Assn., Sectional Committee Y10, Letter Symbols.

► Frank Sisco has been appointed as AIME representative to a three-year term on the National Research Council.

(Continued on page 542)

FALL MEETING PLANS

The 1958 Fall Meeting of The Metallurgical Society of AIME, sponsored by the Institute of Metals Division, promises to be one of interest to all members of the Society. It will be held at the Carter Hotel in Cleveland, October 27-30, 1958. For the first time at this meeting, the Extractive Metallurgy Division will participate with the Institute of Metals Division and the Iron and Steel Division. The complete program, together with available abstracts, will be published in the September JOURNAL OF METALS. Special sessions have been arranged by these technical committees: Titanium, Nuclear Metallurgy, Powder Metallurgy, Semiconductors, Chemistry and Physics of Metals, Refractory Metals, Physical Metallurgy, and Electrical and Magnetic Metals.

The Institute of Metals Division will hold its technical sessions on all four days of the meeting. The Iron and Steel Division and the Extractive Metallurgy Division will hold their sessions on Tuesday, October 28.

The sessions on extractive metallurgy will include a morning session on the *Physical Chemistry of Halide Systems* and an afternoon session on *New Applications of the Phase Rule in Extractive Metallurgy.*

In addition to formal technical sessions, two committees, Semiconductors and Powder Metallurgy, will provide opportunities for informal get-togethers. A luncheon on Monday, October 27, will be sponsored by the Semiconductors Committee, and a luncheon on Thursday, October 30, by the Powder Metallurgy Committee. The Annual Fellowship Dinner will be held on Tuesday evening for all members of The Metallurgical Society and their guests.

The Fall Meeting is being held concurrently with the 40th National Metal Congress and Exposition of the American Society for Metals. Included in the ASM technical program are sessions on such timely topics as High-Temperature Metals, Uranium, and Titanium.

1960: UET PANORAMA

The above photograph simulates a view of the East River and United Nations Building (extreme right) as it will appear to the occupants of the new United Engineering Center in 1960. An up-to-date story on the progress of this UET panorama is detailed below.

AIME members and industrial companies—including companies supplying equipment—have been responding quickly and generously in the Building Fund campaign for the United Engineering Center.

The approach to industry got under way first, and 3 million dollars of the 5 million dollar goal had been reached by June first, with numerous gifts of $25,000 and more, ranging up to $300,000. A tentative target of $100 for each member engineer employed by a company has been set, and this aim has been slightly exceeded in the early returns. The team of Louis S. Cates and H. DeWitt Smith has secured pledges for $600,000 from the nonferrous mining companies, representing 20 pct of total Industry subscriptions to date.

Canvassing of individual engineers, practically all of whom are members of societies that will have a home in the new building, began in the spring. The goal for individual members' subscriptions is 3 million dollars. In the weekly reports of progress made by the different societies, the AIME has consistently ranked at the top—thanks largely to the efforts of H. DeWitt Smith, who took as his assignment the past Presidents of the Institute, and other business friends. The eighteen living past Presidents subscribed a total of $17,395 toward total pledges secured by Mr. Smith for more than $60,000, an excellent start on the AIME quota of $500,000 from its Member Gifts Campaign.

The approach to AIME members in the Mining and Metallurgical Societies has so far been made entirely through the Local Sections. Each Local Section has been asked to submit a list of names of those whom it proposes to canvass personally, and after checking at AIME headquarters to avoid duplications the Section is given the green light to go ahead. Only a limited number of members will be approached at first, as the job will continue for several months. However, by the end of the year it is hoped that all members in the United States will have been approached for a pledge. Thus, this is a report of the excellent progress made to date and not an appeal for a pledge.

The pledges may be paid over a three-year period, and may either be in cash or securities if the latter type payment is more favorable to the payee income-tax-wise or for other reasons.

Aerial view of the new United Engineering Center—light colored structure shown in lower right.

Industrial Campaign

A galaxy of the country's outstanding engineers are heading the campaign. Herbert Hoover is Honorary Chairman and Alfred P. Sloan, Jr., Honorary Vice-Chairman, with Mervin J. Kelly as General Chairman of the National Industrial Committee. It was Mr. Kelly who headed the group that last year promised adequate financing, which was then expected to be about 2½ million dollars. The sights have since been raised to 8 million dollars of new money, of which the Kelly Committee has agreed to raise $5 million and has already received pledges of over $3 million from industrial concerns. The increased target was set after an exhaustive study of the facilities needed and the best location for a building to be the headquarters of international technology, designed for the advancement of America's engineering leadership. John J. McCloy is Treasurer, of the Campaign Fund Committee and the Executive Committee includes Stephen D. Bechtel, Albert Bradley, Louis S. Cates, John L. Collyer, Ralph J. Cordiner, Morse G. Dial, Eugene G. Grace, Henry T.

Heald, Roy T. Hurley, James R. Killian, Jr., Donald C. McGraw, and Philip Sporn.

AIME members on the National Industrial Campaign Steering Committee include Donald H. McLaughlin, who is a co-chairman for northern California; Leo F. Reinartz, who is actively soliciting pledges from the steel companies; H. DeWitt Smith, whose work on the Member Campaign has already been mentioned; Will Mitchell, Jr., who is heading the campaign in Wisconsin and Minnesota; William T. Ahlborg, Wayne L. Dowdey, Jack H. How, William B. Stephenson, Carl E. Reistle, and Herbert A. White, who is spearheading the industrial campaign in Illinois.

Inasmuch as the 10 million dollar United Engineering Center will be in New York City, campaign committees have been especially active there and a substantial part of both the industry and members' quotas will be raised locally. The Greater New York Business Campaign is headed by William H. Byrne as chairman, with Mayor Robert F. Wagner as Honorary Chairman, and President Augustus B. Kinzel, of the AIME, as an active member of the committee. State committees will get to work in the fall.

Members' Gifts Campaign

As already mentioned, the AIME Local Sections are so far responsible for success in the Members' Gifts Campaign. Each has been assigned a tentative quota for early solicitation. Dr. Joseph L. Gillson is heading the work, with Michael L. Haider as Vice-Chairman for Petroleum, O. B. J. Fraser as Vice-Chairman for Metallurgy, and Evan Just as Vice-Chairman for Mining. Edward H. Robie is acting as Secretary for the AIME Members' Gifts Campaign with an office at AIME headquarters.

The site for the new building extends from 47th to 48th St. on First Avenue, facing the United Nations Plaza and just out of the congested midtown area. Old buildings have been demolished and construction of the new Center will start shortly, to be completed for occupancy in 1960.

AIChE Inducted as Founder Society by UET

Induction of the fifty-year old American Institute of Chemical Engineers as a Founder Society by United Engineering Trustees Inc. marked the first time in forty-two years that a national engineering society has been admitted to membership. Attending ceremonies connected with the signing of Founders' Agreements were (above, left to right) seated at the table: David W. R. Morgan, Past President, ASME representing James N. Landis, President, ASME; Augustus B. Kinzel, President, AIME; Walter J. Barrett, President, AIEE and also President, UET; George E. Holbrook, President, AIChE; and Louis R. Howson, President, ASCE. The standing Secretaries (left to right) are: O. B. Schier II, ASME; Ernest Kirkendall, AIME; Steven W. Marras, UET; F. J. Van Antwerpen, AIChE; and William H. Wisely, ASCE.

City Officials Admire New United Engineering Center

The greater New York Business Campaign for the New United Engineering Center got under way this spring, at a luncheon at the Waldorf-Astoria Hotel. City officials saluted the profession of engineering and warmly endorsed the campaign to fund construction of the new national headquarters. Shown above, with a model of the new Center are, left to right: John J. Theobold, Deputy Mayor; Commissioner Richard C. Patterson, Dept. of Commerce and Public Events; William H. Byrne, Chairman of the Greater New York Business Campaign; Mayor Robert F. Wagner; Abe Stark, President of the City Council; and C. F. Preusse, City Administrator.

Headquarters will be provided not only for the Founder Societies, which now include the AIChE as well as the AIME, ASCE, ASME, and AIEE, but for many other societies of which the following have shown an interest: The American Institute of Consulting Engineers, The American Institute of Industrial Engineers, American Rocket Society, American Society of Heating and Air-Conditioning Engineers, American Society of Refrigerating Engineers, American Water Works Association, American Welding Society, Electrochemical Society, Illuminating Engineering Society, Society of Motion Picture and Television Engineers, American Standards Association, and Engineering Foundation.

The building will be twenty stories high, and contain about 250,000 sq. ft. of floor space, for administrative headquarters, publication facilities, meeting and conference rooms, displays and exhibits, and centralized service areas for coordinating such activities as duplication, addressing, and mailing, to assure greater efficiency and economy. The fifty-year-old Engineering Societies Building on 39th St. in New York is now in the heart of the wholesale millinery district and is completely outmoded and inadequate for present needs. In planning the new building it was decided to make it one of which all engineers would be proud for the next half century. With the present emphasis on science and engineering in the world, it will be timely evidence of the progress toward maturity of the engineering profession and of the teamwork and solidarity of members of the engineering societies.

AROUND THE SECTIONS

The Chase Country Club, Wolcott, Conn., was the scene of the Mar. 25, 1958 meeting of the **Connecticut Section.** At the meeting, which was attended by 45 members and guests, a technical talk was presented by I. A. MacArthur, welding engineer with the aluminum technical center of Olin Mathieson Chemical Corp. He discussed the various methods of welding aluminum alloys, covering limitations and advantages of each method. A film presentation, *High Speed Aluminum Welding*, was also shown which depicted many types of automatic welding techniques used on large sections as ship superstructures and tank assemblies.

The following officers were elected for the year July 1, 1958 to June 30, 1959: Chairman, Frank S. Chudy, The Bullard Co., Bridgeport; Vice-Chairman, Richard M. Treco, Olin Mathieson Corp., New Haven; Secretary, Robert S. Bray, Chase Brass & Copper Co., Waterbury; Treasurer, Wm. R. Johnson, Wallace Barnes Co., Bristol; Publicity Chairman, Elmer S. Barnes, Scovill Mfg. Co., Waterbury; Membership Chairman, John P. Lynch, American Brass Co., Waterbury; and Member-at-Large, Alan R. Pels, Bridgeport Brass Co., Bridgeport.

Also at this meeting, members who retired from industry during the past year were made Senior Members of the Connecticut Section. They are: D. R. Hull, B. H. McGar, and J. L. Christie.

On May 16, 1958, the Section held their annual spring party for wives and guests at the Chase Country Club. The program featured dancing from 8:30 to 1:00 a.m., and a buffet supper midway through the evening. Twenty-eight couples attended this gala event.

May 14, 1958 marked the joint meeting of the **New York Powder Metallurgy (Hob-Nob) Group** and the **New York Physical Metallurgy Group,** at the Brass Rail Restaurant, New York City. The featured speaker at the dinner meeting H. J. Williams, member of technical staff, Bell Telephone Laboratories, Murray Hill, N. J., was ill and unable to attend. In his stead the talk *Magnetic Domains in Single Crystals and Their Films* was presented by J. K. Galt also of Bell Telephone Lab. It included a general discussion of magnetic domains in crystals, and ensued with recent work on magnetic writing on thin films and domains in transparent crystals. The talk was illustrated with movies on the movement of domain boundaries.

May 16, 1958 marked the meeting of the **Oregon Section,** held at Burns Restaurant, Portland, Ore. An attendance of 29 heard the guest speaker, R. G. Vervaeke, general manager, Chemical Lime Co., Baker, Ore., talk on *The Chemical Lime Story of Blue Mountain Lime Products.*

At the meeting, a motion was passed that the Oregon Section give a vote of Confidence to Frank Cappa, AIME representative to the Oregon Technical Council. Mr. Cappa was urged to assure the American Institute of Architects that the Section is with them in their stand against Judge Frank Lonergan's decision overriding the Oregon State Board of Architect Examiners' refusal to issue a license to an applicant.

At the June 20th meeting of the Section at Burns Restaurant, Mr. Rochon, chief chemist for Harvey Aluminum Co., The Dalles, Ore., was the featured speaker.

Field Trip Held at Atomic Power Station

The Shippingport Atomic Power Station of the Duquesne Light Co. was the target for the **Pittsburgh Section's** all-day field trip launched on May 2, 1958. The Shippingport plant was described in detail to the 68 members attending, by guides of Duquesne Light Co., with the aid of display models. Visitors viewed the canal area above the reactor, control area, turbine-generator area, waste disposal set-up, and certain laboratory and health facilities.

After lunch, members traveled to the Josephtown Smelter of St. Joseph Lead Co. to observe the integrated zinc smelting operations in which zinc sulfide concentrates were roasted, the sulfur dioxide gases are converted to sulfuric acid, the roaster calcines are sintered, and sinter is reduced to zinc metal in electrothermic furnaces. Laboratory facilities and operations relating to zinc oxide and to cadmium production were also observed.

The plant visitations were sponsored by the recently-formed Mineral Industry Group of the Pittsburgh Section.

At a luncheon held May 15, at the Sherwyn Hotel, Pittsburgh, C. Law McCabe, outgoing chairman of the Pittsburgh Secton, turned over the duties of chairmanship to Jack Vonfeld, who will be assisted by J. H. Henderson, vice-chairman; R. S. Crowell, secretary; and J. H. Melvin, Treasurer.

Board of Directors

(Continued from page 539)

► Andrew Fletcher and Frank Sisco will represent AIME on the Engineering Societies Library Study Committee.

► Revised Bylaws of the Florida Section have been approved.

► The AIME Research Committee has approved sponsorship by the Engineering Foundation of the following projects: project 32, *Alloys of Iron*, under Alloys of Iron Committee, Frank T. Sisco, director; project 80, *Heat Flow in Quenching*, under Victor Paschkis, Columbia University; project 97, *Diffusion in Steel*, under Morris Cohen, Massachusetts Institute of Technology; project 104, *Comminution*, under J. H. Brown, MIT; project 110, *Corrosion Research Council*, under the chairmanship of F. L. LaQue; project 112, *Flow of Bulk Solids*, under Andrew Jenike at Utah Engineering Experiment Station; project 123, *Thickening and Thickeners*, under A. M. Gaudin, MIT. The tentative project 135, *Documentation Research in Engineering*, by Center of Documentation and Communication Research, Western Reserve University, has been approved on the basis that the majority of members feel this is a worthwhile endeavor, although some members expressed doubts that this work is within the scope of interests of the Engineering Foundation.

► Establishment of a Student Chapter at Marietta College, Marietta, Ohio, has been approved and Bylaws accepted subject to changes suggested.

► D. O. Kennedy has been reappointed AIME representative to the Joseph A. Holmes Safety Assn. at the annual meeting of the association.

► John M. Lovejoy and his two alternates, Michael Haider and Harold Decker, have been reappointed for six-year terms as AIME representative and alternates on the Hoover Medal Board of Award.

► Nicholas M. Lazar has been appointed representative of The Metallurgical Society on the ECPD Professional Training Committee.

► Approval has been given for the Henry L. Doherty Memorial Fund Committee recommendation that the following be published by the Society of Petroleum Engineers and charged to the Fund income: 1) one instruction folder to accompany film, *Your Career in the Petroleum Sciences;* 2) one review folder for the same purpose; and 3) 6000 copies of booklet, *Careers in Petroleum Engineering.*

Nuclear Congress to Be Held, April 1959

Preliminary plans for the Fifth Nuclear Congress to be held in Cleveland, April 1959, were recently announced by Engineers Joint Council. Engineers and scientists who would like to present technical papers during the Congress were invited to submit outlines before Oct. 1, 1958.

As in the past, the Congress will be composed of four parts: The Nuclear Engineering & Science Conference, the Hot Laboratories & Equipment Conference, the Atomic Energy Management Conference, and the Atomfair at which nuclear equipment will be on display. Scene of the Conference will be the Cleveland Auditorium, April 5 to 10.

Clarke Williams of Brookhaven National Laboratory, chairman of the Nuclear Engineering & Science Conference, announced that papers will be considered for inclusion in the 1959 Program if summaries are submitted before Oct. 1, 1958. He stated that prospective authors should submit 300-500 word summaries of proposed papers to the secretary of any one of the sponsoring societies. A list of sponsoring groups is available from *Engineers Joint Council, 29 W. 39 St., NYC.*

Mr. Williams added that papers selected will be those presenting the most recent and outstanding developments in the nuclear field. Topics in the past have included reactor design, power plants, radiation techniques, instrumentation, shielding, waste disposal subjects.

For general information on the Congress contact: *T. A. Marshall, Jr. (Congress Manager) or L. K. Wheelock (Asst. Manager) c/o Engineers Joint Council, 29 W. 39 St., New York 18, N. Y.*

Nuclear Congress Preprints Still Available

There is still a complete stock of preprints for the Nuclear Engineering and Science Conference and the proceedings of the Hot Laboratories and Equipment Conference from the 1958 Nuclear Congress held at the Chicago International Amphitheatre, Mar. 17-21, 1958. Publication of the transactions of this conference in one volume is not planned.

As the preprints and proceedings will not be reordered, it is suggested that those planning to purchase copies do so at once to avoid disappointment.

The proceedings of the Hot Laboratories and Equipment Conference sell for $10.00 per bound volume. The preprints sell for $.50 per copy. Listed, are some of the preprints available:

HIGH TEMPERATURE MATERIALS CONFERENCE LUNCHEON

Shown seated at the guest table during the AIME High Temperature Materials Conference Luncheon, held on May 6, 1958, at the Ambassador Hotel, Los Angeles, were left to right: J. M. Denney, California Institute of Technology, (CIT), Metals Program Chairman; W. V. Wright, Electro-Optical Systems, Metals Conference Chairman; Pol Duwez, CIT, 1957 Metals Program Chairman; G. M. Giannini, Giannini Research Laboratories, Speaker; and R. H. Thielman, Stanford Research Institute, General Conference Chairman.

13) *Comparison of the Active with the Inactive Uranium Dioxide-Oxygen System*—AIME—D. A. Vaughan and R. K. Willardson, Battelle Memorial Institute.

18) *Effects of Pile-Irradiation on U_3Si*—AIME—M. L. Blilber and L. J. Jones, Westinghouse Electric Corp.

193) *The Zirconium-Uranium Dioxide Reaction*—AIME—A. F. Gerds, J. W. Droege, M. M. Mallet, and A. W. Lemon, Jr., Battelle Memorial Institute.

17) *The Effects of Transformation Cooling Rate on the Activation Energy Required for Recrystallization of Beta Quenched Uranium*—AIME—H. R. Gardner and J. W. Riches, General Electric Co.

172) *Kinetics of the Beta Transformation of Uranium*—AIME—William R. McDonell, Savannah River Lab.

63) *Electron Metallography of the U-Ni Diffusion Zones*—AIME—C. L. Angerman, E. I. du Pont de Nemours & Co. Inc.

16) *Cermet Control Rod Fabrication by Powder Rolling*—AIME—Samuel Strochheim, Metals Res. & Development Inc.

62) *Melting and Fabrication of a Silver Base Alloy for Control Use in Nuclear Reactors*—AIME— R. J. Haffeman, W. B. Haynes, and R. W. Tombaugh, Westinghouse Electric Corp.

19) *Metallurgical Design and Properties of Silver-Indium-Cadmium Alloys for PWR Control Rods*—AIME—I. Cohen, E. F. Losco, and J. D. Eichenberg, Westinghouse Electric Corp.

31) *A Study of Aluminum Uranium Alloys Containing up to 45 w/o Uranium*—AIME—N. E. Daniel, E. L. Foster, and R. F. Dickerson, Battelle Memorial Institute.

43) *LMFR Breeder Blanket Preparation by Fusion Electrolysis*—AIME—M. E. Sibert, A. L. Cunningham, and M. A. Steinberg, Horizons Inc.

15) *Physical Factors in the Gainesville, Florida, Area Affecting Site Location of a One Megawatt Nuclear Research Reactor*—AIME—Stanley O. Reichert, University of Florida.

37) *Radiation Damage Studies of Seven Non-Fissionable Metals*—AIME—C. A. Bruch, and W. E. McHugh, General Electric Co.

194) *Corrosion Studies in Organic Heat Exchange Media*—AIME—W. K. Boyd, G. L. Ericson, O. M. Stewart, and P. D. Miller, Battelle Memorial Institute.

14) *Geological and Hydrologic Guides to the Ground Containment and Control of Wastes at Hanford*—AIME—R. E. Brown, and W. H. Bierschenk, General Electric Co.

173) *Development of a Wafer-Type Fuel Element for the Experimental Breeder II*—AIME—S. I. Megeff, F. E. Bowman, and H. S. Kalish, Sylvania-Corning Nuclear Corp.

38) *The Fabrication of Stainless Steel-UO_2 Fuel Plates*—AIME—W. R. Weinberger and H. S. Kalish Sylvania-Corning Nuclear Corp.

133) *High Temperature Fatigue Testing—with Application to Uranium*—AIME—Jack R. Bohn, and Glenn Murphy, Iowa State College.

A complete list of titles can be obtained from the *American Institute of Chemical Engineers, 25 West 45 Street, New York 36, N. Y.*

National AIChE Meet to Follow Rocky Mt. Meeting

A national meeting of the American Institute of Chemical Engineers will be held in Salt Lake City immediately succeeding the AIME 5th Annual Rocky Mountain Minerals Conference. The AIME conference will be held in Salt Lake City, September 17, 18, and 19, with headquarters at the Newhouse Hotel. The AIChE meeting with headquarters at Hotel Utah, starts Sunday, September 21st, and runs through Wednesday, September 24th.

To Hold Vacuum Symposium In San Francisco

The American Vacuum Society, formerly the Committee on Vacuum Techniques, will hold the Fifth National Vacuum Symposium at the Sir Francis Drake Hotel, San Francisco, on Oct. 22 to 24, 1958. The Society annually presents in symposium an international representation of chemists, physicists, metallurgists, and other scientists and technologists whose work furthers the knowledge of the properties of vacua and new processes developed for science and industry through the use of vacuum techniques.

The program is conveniently divided into several categories: fundamental basis of vacuum techniques, applications of vacuum in pure and applied science, vacuum systems and components thereof, instrumentation and controls, and vacuum processes and their industrial application.

Among the list of papers accepted to date for presentation at the San Francisco Symposium are: *Mechanism of Gas Removal from Liquid Metal in Vacuum* by A. M. Samarin and R. A. Krassev, Academy of Sciences, Moscow, USSR, and *Some Properties of Vacuum Treated Bessemer Steel* by A. M. Samarin and R. A. Krassev, Academy of Sciences, Moscow, USSR.

W. H. Eisenman Dies

William H. Eisenman, Secretary of the American Society for Metals for forty years, died in La Jolla, Calif., on May 30, 1958.

Mr. Eisenman joined the American Society for Steel treating, forerunner of ASM in 1918 as national secretary. Under his leadership the Society grew from a one-desk organization, with fewer than 200 members to more than 30,000 members in 105 chapters in the U. S. and Canada.

As national Secretary he directed the National Metals Congress and Exposition, the nation's largest industrial exposition, and in 1951 organized and directed the world's first Metallurgical Congress.

In October, 1956, when Mr. Eisenman began his twentieth, two-year term as national secretary, he received the society's highest award "for devotion of a lifetime to the promotion of metallurgical research and knowledge."

OBITUARIES

Vsevolod N. Krivobok, (Member 1921) well-known authority on stainless steels and supervisor of the stainless steel and heat resistant alloy section of the development and research div. of The International Nickel Co. died in St. Luke's Hospital, New York, after a brief illness, on May 1, 1958. Born in Poltava, Russia, Dr. Krivobok was a naturalized United States citizen. A graduate of St. Petersburg, Russia, Polytechnic Institute, dept. of metallurgy in 1916, he attended Harvard University where he received a B.S. degree in metallurgy in 1921, degree of metallurgical engineer in 1922, and a Doctor of Science degree in 1924.

From 1924 to 1934, Dr. Krivobok was a member of the Metallurgical Research Bureau of the Carnegie Institute of Technology. He served as a faculty member and professor of metallurgy at MIT to 1940, while also serving as associate director of research for the Allegheny Ludlum Steel Corp., Brackenridge, Pa., 1934

Change of Address and Personals Form

To be sure that you receive your publications and correspondence promptly, please fill in the form below and send it to **The Metallurgical Society of AIME**, 29 W. 39th St., New York 18, N.Y.:

Name _____

Old Address _____

_____

_____

New Address _____

_____

_____

Personals: Please list below your former company and title and your new title and company (or new work) for use in JOURNAL OF METALS. (Copy deadline for personals items is six weeks before date of issue.)

Former Company _____

Former Title _____ Length of Time There _____

New Company _____

New Title _____ Date of Change _____

Any recent activity that would be of interest to members:

_____

_____

_____

_____

PROPOSAL FOR AIME MEMBERSHIP

I consider the following person to be qualified for membership and request that a membership kit be mailed to him:

Name of Prospective Member:

_____

Address

_____

_____

_____

Name of AIME Member:

_____

Address

_____

_____

_____

to 1941. Prior to joining International Nickel's development and research div. in New York in 1944, Dr. Krovobok had been director of research and chief metallurgist of Lockheed Aircraft Corp., at Burbank, Calif., since 1941.

He contributed greatly to the scientific knowledge of stainless steels during the early stages of their development. Subsequent technical contributions in this field made him a recognized authority both in this continent and abroad.

In 1934, Dr. Krivobok was the Campbell Memorial Lecturer for the American Society for Metals, and presented the Sauveur Memorial Lectures for this Society in 1939 and 1943. He was chairman of the high alloys committee of the Welding Research Council, a retired Trustee and member of ASM, and a member of AIME, American Society for Testing Materials, American Welding Society, British Iron and Steel Institute, and the British Institute of Metals.

Frederic A. Eustis (Legion of Honor 1902) died at Boston on May 21, 1958. Mr. Eustis was born in Milton, Mass., in 1877. A graduate of Harvard University (1901), he received the degree of Doctor of Science in 1915. He also attended the Massachusetts Institute of Technology. From 1917 to 1919, he served as special agent for the U. S. Shipping Board, Cleveland, and until his illness, was a director of the Penobscott Chemical Fibre Co.

Mr. Eustis was a member of AIME, the American Chemical Soc., Mining and Metallurgical Soc., and the Mfg. Chemists Assn. He had served in official capacity and was active for many years in the affairs of the Compressed Gas Assn.

Martin Wm. Offinger (Member 1945) passed away on Apr. 30, 1958 at Camden, N. J. Mr. Offinger was born in New York City on Oct. 14, 1911. He graduated from the University of Maine in 1933, with a B.S. degree. In 1934, he joined Handy & Harman as a research assistant in the metal powder laboratory. After leaving the company in 1941, Mr. Offinger was employed for six months by Westinghouse Laboratories, East Pittsburgh, Pa., as a research engineer. From 1941 to 1943 he was a research fellow at Stevens Institute, Hoboken, N. J. He served as a research engineer with Westinghouse Lamp Div., Bloomfield, N. J., from 1943 to 1947. Mr. Offinger became associated with General Electric Co., Schenectady, N. Y., as a research engineer, metallurgical div., in 1947. In 1953 he began work with Magnetic Metals Co., Camden, N. J., where he served until the time of his death.

T. L. Binswanger (Member 1949) died recently. Born in Washita, Okla., Feb. 2, 1899, Mr. Binswanger was employed by the Madera Co. Ltd., at Madera Chihuahua, Mexico from 1921 to 1924 as chief power plant engineer and electrician for box factory and planning mill. From 1924 to 1932, he served the American Smelting & Refining Co. Smelting Dept. of Mexican Div. In 1932 he joined The Fresnillo Mining Co., at Fresnillo, Zacatecas, Mexico. He left the company in 1933, and mined for gold ore near San Pedro, Corralitos, Chihuahua, Mexico to 1936. Mr. Binswanger returned to The Madera Co. Ltd. from 1937 to 1938, serving in their power plant at Madera, Chihuahua. He contracted with the Dolores Mining Co. (1938-39) at Dolores, Chihuahua, Mexico, to operate their mill for six months on a commission basis. From 1940 until the time of his death, Mr. Binswanger was employed by U. S. Potash Co., Carlsbad, N. M.

Richard Sutro (Member 1928) passed away recently. At the time of his death, he was residing in New York City.

NECROLOGY

Date Elected	Name	Date of Death
1949	T. L. Binswanger	Unknown
1902	Frederic A. Eustis Legion of Honor	May 21, 1958
1921	V. N. Krivobok	May 17, 1958
1945	M. Wm. Offinger	Apr. 30, 1958
1928	Richard Sutro	Unknown

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on June 1, 1958 was 30,162; in addition 3,064 Student members were enrolled.

ADMISSIONS COMMITTEE

J. H. Scaff, Chairman; Alfred Bornemann; F. B. Foley; T. D. Jones; L. L. Seigle; J. M. Warde; H. K. Worke.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Frank C. Anderko, Bethlehem, Pa.
Robert W. Anderson, Markham, Ill.
Benjamin F. Anthony, Cleveland, Ohio
Anthony Arrott, Dearborn, Mich.
Ambrose C. Sedlachek, Everet, Mass.
Clifford W. Spicer, Pitcairn, Pa.
William Taddeo, Steelton, Pa.
Anton J. Tomasek, St. Louis, Mo.
Linwood G. Tucker, Jr., Pittsburgh
Richard W. Vollmer, Pittsburgh
Brian H. C. Waters, Letchworth, Herts, England
Monroe S. Wechsler, Oak Ridge, Tenn.
Peter Wikete, Jr., East St. Louis, Ill.
Heinz Wittstruck, Geneva, Switzerland
Edwin O. Woster, Columbia Falls, Mont.
Kenneth R. Bartholomew, Pontiac, Mich.
F. Bruce Bevelheimer, Pittsburgh
Ralph J. Brady, Chicago
Walter E. Carbone, New York City
Cornelius M. Cosman, New York City
Harry J. DeRolf, Pittsburgh
Richard R. Douglas, La Habra, Calif.
Rudolf M. Fichte, Nurnberg, Germany
William J. Flynn, Gary, Ind.
Richard W. Hardt, Schenectady, N. Y.
Michael V. Herasimchuk, Bethlehem, Pa.
Carl F. Hoffman, Sparrows Point, Md.
E. Warren Hunziker, Provo, Utah
William P. James, Detroit
W. Dwight Kimzey, Columbia Falls, Mont.
John W. Knappert, Buffalo, N. Y.
H. I. Martin, Pittsburgh
John B. Mitchell, Pittsburgh
George J. Morris, Chagrin Falls, Ohio
Jacques Neve, Sclessin-Ougree, Belgium
John I. Orrison, Monessen, Pa.
Gustav W. Pirk, Utica, N. Y.

Associate Members

Daniel Baker, Monkton, Md.
Hansil O. Bias, Cleveland
William E. Boyd, Indianapolis
Rudolf E. Chope, Englewood, Colo.
Lewis A. Harrison, Mexico, Mo.
Harold T. Hunter, Ambler, Pa.
William J. McGregor, Pittsburgh
Roger J. Moore, Montreal, Canada
Charles M. Rader, Pittsburgh
J. S. Reed, Lowellville, Ohio
James H. Roman, Cleveland
Gilbert R. Rothschild, Berkeley Heights, N. J.
Maurice A. Young, Youngstown, Ohio

Junior Members

Francis X. Brown, Drexel Hill, Pa.
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COMING EVENTS

Sept. 10-12, AIME Rocky Mountains Mineral Conference, Newhouse Hotel, Salt Lake City.

Oct. 3-4, AIME NOHC Southern Ohio Section, fall meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Oct. 9-10, AIME NOHC Southwestern Section, fall meeting, Tutweiler Hotel, Birmingham, Ala.

Oct. 10, AIME NOHC Eastern Section, fall meeting, Warwick Hotel, Philadelphia.

Oct. 16, AIME Utah Section, *Progress in Air Pollution Control*, Salt Lake City.

Oct. 27-30, AIME Fall Meeting of The Metallurgical Society, sponsored by the Institute of Metals Division, Carter Hotel, Cleveland.

Nov. 7, AIME Pittsburgh Section, Thirteenth Annual Off-the-Record meeting, Pittsburgh.

Nov. 11, AIME NOHC Buffalo Local Section, fall meeting, Statler Hotel, Buffalo.

Nov. 17-20, The Fourth Conference on Magnetism and Magnetic Materials, sponsored by the AIEE, in cooperation with The Metallurgical Soc. of AIME, The American Physical Soc., the Inst. of Radio Engineers, and the Office of Naval Research, Sheraton Hotel, Philadelphia.

Dec. 3-5, AIME 16th Electric Furnace Conference, Statler Hotel, Detroit.

Dec. 11, AIME Utah Section, Panel discussion on the Place of Research in the Minerals Industries, Salt Lake City.

Feb. 15-19, 1959, AIME Annual Meeting, St. Francis Hotel, Sheraton-Palace Hotel, and Sir Francis Drake Hotel, San Francisco.

Apr. 2-3, 1959, AIME Technical Conference on Stress Corrosion, Mellon Institute, Pittsburgh.

Apr. 6-8, 1959, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 27-30, 1959, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPA.

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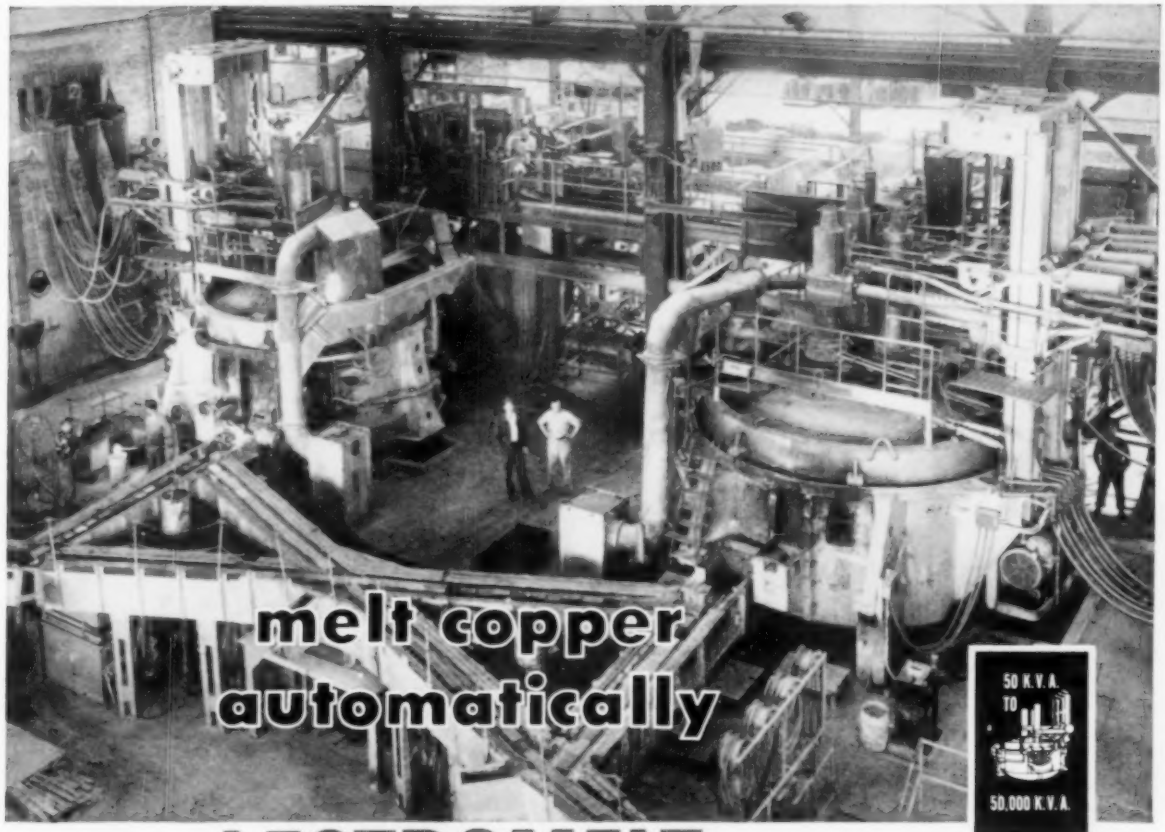

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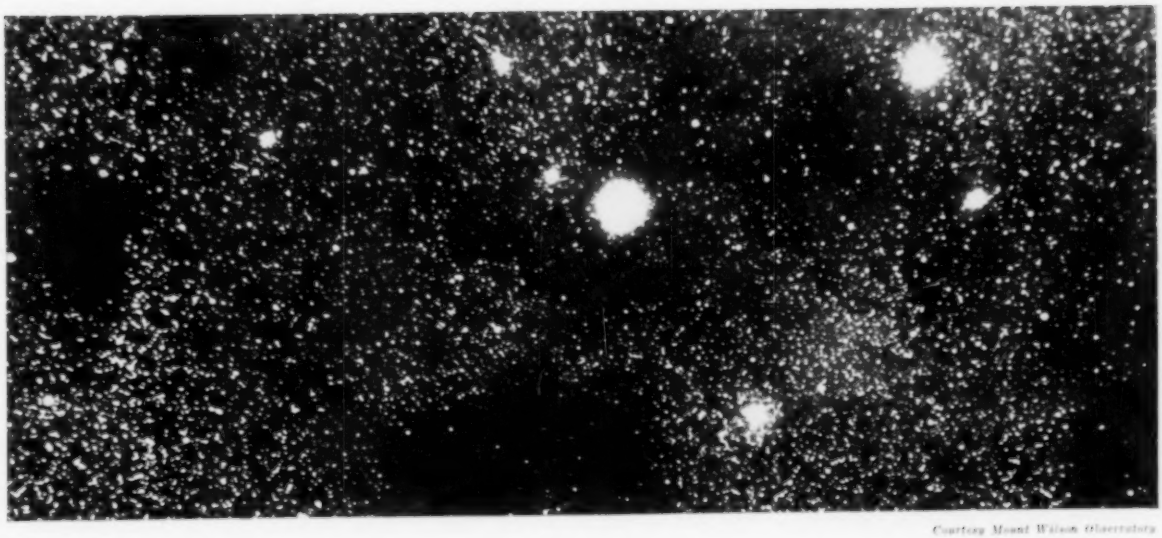

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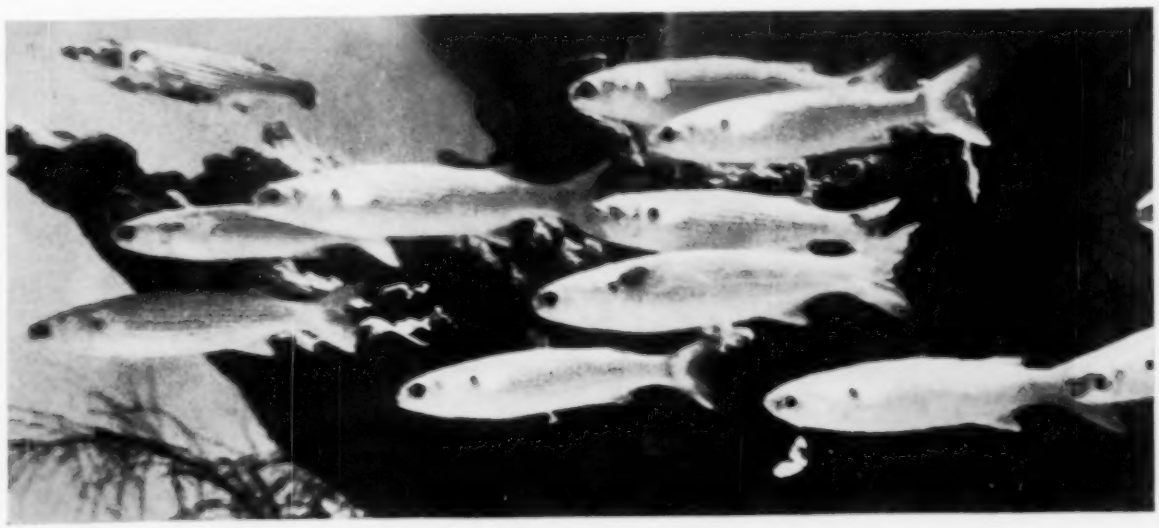
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